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# Foreword

By J. Jeffery Goebel and Jim Benson\*

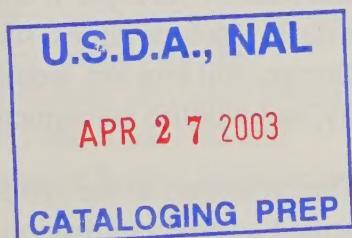
Since the time that the Soil Conservation Service completed the 1992 National Resources Inventory (NRI), the agency's name has changed to reflect its expanded mission. Nevertheless, the agency, now the Natural Resources Conservation Service (NRCS), remains committed to providing information on the status, conditions, and trends of the natural resources on the Nation's nonfederal lands. Its primary tool for doing this is the NRI.

## What Is the NRI?

The NRI is an inventory of land cover and use, soil erosion, conservation treatments in place and needed, prime farmland, wetlands, and other natural resource characteristics on the nonfederal rural land of the United States. But to think of the NRI as an assemblage of data on several discrete elements of the Nation's rural environment would be misleading. Rather, the NRI allows for analyses that encompass various aspects of the natural resource base simultaneously. And, the NRI is linked to the agency's extensive Soils Interpretations Records data base to provide additional soils information. In this way, the NRI provides a record of the Nation's conservation accomplishments and future needs.

Because natural resource issues are temporal and spatial in nature, the NRI data base is a unique source of information that provides analysts a means to properly study these issues. Analyses using NRI and associated data are best performed using a geographic information system, or GIS.

The NRCS conducts NRIs at 5-year intervals to determine the conditions and trends in the use of soil, water, and related resources nationwide. The NRI program has been developed and conducted in cooperation with Iowa State University's Statistical



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Laboratory, and with guidance from several Federal and state agencies.

The 1992 NRI is the most comprehensive inventory yet conducted, covering some 800,000 sample sites representing the Nation's nonfederal land—nearly three-fourths of the country's total land area. Information is available for 3 years—1982, 1987, and 1992—to make possible analyses of changes and trends in land use and natural resource conditions over the period.

The purpose of the NRI is to provide information that can be used for effectively formulating policy and developing natural resource conservation programs nationally and statewide.

NRI information has historically been used to address national, regional, and state agro-environmental issues. Many provisions of the 1985 and 1990 farm bills were formulated using NRI information. NRI data have been used to model soil productivity, assess impacts of conservation programs on the condition of grazing lands, examine changing patterns in wetland conversion, assess offsite effects of soil erosion, and identify areas particularly vulnerable to ground water contamination from agrochemical use.

The 1992 NRI will play an even more important role in policy development. Assessments and analyses will be conducted during formulation of the next farm bill and other environmental legislation. There will be assessments of water quality benefits expected from implementation of government policies that facilitate farmer adoption of management practices that reduce chemical use. The Soil and Water Resources Conservation Act (RCA) appraisal and the National Conservation Program will be updated during the next 2 years, using NRI as its analytical base.

The NRI continues a 60-year history of natural resources conducted by NRCS and its predecessors, the Soil Erosion Service and the Soil Conservation Service. The NRI is heir to a tradition begun with the National Erosion Reconnaissance Survey in 1934 and continued by Conservation Needs Inventories in 1945, 1958, and 1967. The initial NRI was conducted in 1977, with successors in 1982, 1987, and 1992.

The first release of 1992 NRI data was made in July 1994 at a news conference conducted by Deputy Secretary of Agriculture Richard Rominger; Assistant Secretary (now undersecretary) of Agriculture for Natural Resources and Environment James R. Lyons; and Soil Conservation Service (now NRCS) Chief Paul W. Johnson.

## The Symposium

*The National Resources Inventory Environmental and Resource Assessment Symposium* was held July 19–20, 1995—the week following the news conference—at Georgetown University, Washington, DC. It was coordinated by Linda K. Lee of the University of Connecticut. The symposium was designed for policy analysts, researchers, and others interested in environmental and natural resource issues, such as land-use change, soil erosion, wetlands, water quality, and wildlife assessment.

The presenters at the symposium represented a variety of disciplines and backgrounds, but all had extensive experience in analyzing natural resource issues and trends using NRI data. The goals of the symposium were to provide NRI data users with an overview of the 1992 NRI and with resource assessment and modeling applications that can be conducted with the data, and to obtain feedback from a variety of data users about needs and issues that should be considered for the 1997 NRI.

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The symposium provided the first public release of data analysis from the 1992 NRI. Analysis is ongoing—in the NRCS's Natural Resources Inventory Division at agency headquarters in Washington, DC, and other agency locations; in other Federal agencies, such as the General Accounting Office and the Office of Technology Assessment; and in universities, nonprofit organizations, and businesses across the country.

Two points made throughout the symposium bear repeating here. First of all, the analyses presented in these proceedings are preliminary. Further analyses are needed to fully understand the data. And second, NRI data are statistically reliable for national, regional, and—in most cases—statewide analyses but generally should not be used in analyses for areas smaller than states.

**Francis J. Pierce and Peter Nowak** (page 1) look at soil erosion, historically the principal natural resource concern on agricultural lands, and at soil quality, an emerging area of study that is not well addressed in the NRI. They note the dramatic decrease in soil erosion over the 1982–92 period and look to land retirements under the Conservation Reserve Program and to improved conservation practices such as conservation tillage as the primary reasons for the change. Pierce and Nowak also raise several interesting questions about the NRI and suggest ways to improve further inventories.

**Linda K. Lee** (page 24) notes that NRI estimates of land-use changes from 1982 to 1992 appear to be consistent with other data on the subject, especially those from the Bureau of the Census and the Economic Research Service. Lee focuses on the conversion of rural land to urban and developed uses, on reductions in the extent of prime farmland and cropland, and on the possibilities for future land conversions to cropland.

The highly charged issue of wetlands is the topic of **Ralph E. Heimlich** (page 31), particularly as the NRI data can support policy analysis. He notes that NRI data are reliable for national analysis but inappropriate for specific, local analyses. Heimlich examines what he terms “more or less reliable data” on extent and trends of wetlands. He sees a trend of falling conversions of wetlands since the earliest scientific wetland inventories in the 1950's and ascribes the change to a combination of economic conditions and policy changes.

Since the symposium, the White House Office of Environmental Policy has brokered an agreement among the Federal agencies involved on how to interpret NRI wetland figures.

**Michael R. Dicks and John E. Coombs** (page 50) use NRI data to examine the Conservation Reserve Program (CRP), a temporary land retirement program with conservation objectives. They note differences in erosion reduction arrived at through CRP files and the NRI and speculate as to the reasons the differences exist. Dicks and Coombs credit producers with improving their conservation performance and comment on the significance of this in light of possible regulatory legislation.

The NRI also has regional applications, as **Margaret Stewart Maizel, George Muehlback, Paul Bayman, Jennifer Zoerkler, Tom Iivari, Darlene Monds, and Paul Welle** (page 70) show in their discussion of the NRI as it relates to decision-making in the Chesapeake Bay watershed. The authors note that the NRI was originally conceived, and continues to evolve, as a multi-resource inventory and is compatible with geographic information systems (GIS) technology. More specifically, they outline how they used NRI data in constructing a

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system for targeting watersheds for cooperative regional conservation programs.

The NRI helps fill a gap in our understanding of wildlife and wildlife habitat, according to **Steve J. Brady and Curtis H. Flather** (page 92). The authors review the results of two case studies of different scope and recommend improvements in the NRI—expanding data collection to Federal lands, digitizing land cover, and including biological data in the NRI.

**Michael R. Burkart, Mason J. Hewitt, S.L. Oberle, and D.E. James.** (page 102) used the NRI to characterize several agricultural production areas and show how the natural resources in these areas have been altered to support farm production. They contend that research into agroecosystems—ecosystems that have been changed to support agriculture—will help us understand agricultural processes in the broadest manner, and that NRI data can help isolate areas where programs to mitigate natural resource degradation can be most effective.

**Frank E. "Fee" Busby** (page 118) discusses the long and winding road toward development of consistent standards to define rangeland conditions. Busby notes that the NRI does not collect or interpret the data needed to assess rangeland health but left the door open for the NRI as the tool for collecting the appropriate rangeland data.

**Clayton W. Ogg** (page 126) begins his look ahead at emerging opportunities for using NRI data by looking back at how the NRI helped shape the landmark 1985 and 1990 farm bills. In the future, Ogg believes, the NRI could provide information on ecological systems, especially riparian systems, which could be the coming focus of national environmental policy.

## NRI data

Multi-disciplinary data collection teams headed by state resources inventory specialists were responsible for conducting the 1992 NRI. The data collection process depended heavily on remote sensing techniques (particularly photo-interpretation), state-of-the-art data entry software, increased emphasis on training of the data collectors, nationwide georeferencing of all sample site locations, and a comprehensive quality assurance program.

Data collection began in the fall of 1991 and concluded in June 1993. Data were monitored and reviewed to reflect 1992 growing season conditions. Data collected for the 1982 and 1987 NRI's were carefully checked to make sure that definitions and concepts were applied consistently for all three points in time. The data entry software contained sophisticated data checking to help ensure that 1982, 1987, and 1992 measurements were made consistently to allow for more accurate trending analyses.

The NRI data base may seem at first to be large and complex—and without question it is large—but in fact it is both powerful and easy to use.

The data base contains millions of pieces of information. It was constructed:

- to ensure that data for the three most recent surveys—in 1982, 1987, and 1992—are completely comparable and consistent so the data reflect true trends and allow for temporal analyses;
- to reflect growing season conditions for the inventory year;
- to be multi-resource covering many themes and facets instead of just one or two; and
- to combine with NRCS's extensive soil interpretations data base.

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The statistical techniques used for the 1992 NRI have been carefully developed over decades of cooperative research and application and are accepted by the scientific community.

Further information on the sample design, data collection procedures, and data base construction is available in the training modules developed for the 1992 NRI. Contact the authors for a copy. For information on how to obtain data from the 1992 NRI, please see the box on the inside back cover of these proceedings.



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# **Soil Erosion and Soil Quality: Status and Trends**

**By Francis J. Pierce and Peter Nowak\***

The National Resources Inventory (NRI) provides a comprehensive inventory on the occurrence and distribution of soil erosion on non-federal lands in the United States. The 1992 NRI includes the 1982 and 1987 inventories and thus provides the first opportunity to assess long-term trends in soil erosion in the United States.

Since the years 1982 to 1992 represent an era of innovations in soil and water conservation, in both public policy and adoption of on-land soil conservation practices, significant reductions in soil erosion would be expected over this period. This paper takes a first look at the 1992 NRI to assess how soil erosion has changed in the U. S. over the period of the NRI 1982 to 1992, what may have caused the observed changes, and the potential impacts of erosion on soil quality.

Before proceeding, we note some important caveats about the NRI and our analysis of the data. Not all forms of soil erosion were inventoried in the NRI. The NRI estimates sheet and rill erosion based upon the Universal Soil Loss Equation (USLE) and wind erosion based upon the Wind Erosion Equation (WEQ). The NRI inventoried primarily non-federal rural land (e.g., federal lands were omitted). The NRI is a monitoring program - therefore, it says little about the process that caused the changes - these must be inferred to a large extent. There are no direct measures of soil quality in the NRI. We recognize that the NRI data set alone is not sufficient to answer all relevant questions about soil erosion - other data sets must be brought into the analysis. Our analysis of these data is based on the information and codes provided by the USDA Soil Conservation Service. We had to rely on the measurement techniques,

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coding decisions, and data explications provided in the primary NRI data set. The validity of these data management decisions are beyond the purview of this paper. Finally, our analysis is based on highly aggregated summaries of the NRI data, and, therefore, care must be taken in the interpretation of our tables and figures.

### Status and Trends in Soil Erosion over the Period 1982 to 1992

Nationally, the rate of soil erosion, caused by either water and wind, declined over the period 1982 to 1992 for non-federal land in the United States (Table 1).

**Table 1.** Estimated sheet and rill erosion on non-federal rural land by land cover/use for 1982, 1987, and 1992.

| Land Use                               | 1982 | 1987 | 1992 |
|--|------|------|------|
| tons ac <sup>-1</sup> yr <sup>-1</sup> |      |      |      |
| <u>Water Erosion</u>                   |      |      |      |
| Cropland<br>(cultivated)               | 4.5  | 4.1  | 3.5  |
| Cropland<br>(non-cultivated)           | 1.1  | 1.2  | 0.9  |
| Pastureland                            | 1.1  | 1.0  | 1.0  |
| Rangeland                              | 1.2  | 1.2  | 1.2  |
| <u>Wind Erosion</u>                    |      |      |      |
| Cropland<br>(cultivated)               | 3.7  | 3.7  | 2.8  |
| Cropland<br>(non-cultivated)           | 0.5  | 0.5  | 0.4  |
| Pastureland                            | 0.1  | 0.1  | 0.1  |
| Rangeland                              | 4.7  | 4.4  | 4.4  |

(Source: 1992 NRI)

Most of the reduction in erosion occurred on cultivated cropland, where the potential for soil erosion is generally greatest. There was little change in soil erosion rate

in other land uses. The change in erosion rate was greatest from 1987 to 1992, with essentially no change in wind erosion from 1982 to 1987. Sheet and rill erosion on cultivated cropland was reduced 8.9% from 1982 to 1987 and an additional 14.6% from 1987 to 1992, for a net reduction of 22.2 % from 1982 to 1992. Wind erosion on cultivated cropland declined 22.6 % from 1987 to 1992. In 1992, cultivated cropland continued to have the highest sheet and rill erosion rates and high wind erosion rates. Rangeland had the highest wind erosion rates of all land use/cover categories with little change between 1982-1987 and 1987-1992.

When aggregated by state, soil erosion and the pattern of change varied considerably for the two measurement periods, 1982-1987 and 1987-1992. Since cultivated cropland had the highest erosion rates and contributed most to changes in erosion, we will focus our discussion specifically on cultivated cropland.

Average sheet and rill erosion rates and changes over time on cultivated cropland are summarized by state in Table 2. For sheet and rill erosion from 1982 to 1987, 9 states showed no net change, 15 states increased erosion rates from 1.4 to 31.2 %, and 26 states reduced erosion rates from 1.6 to 30.8 % (Tables 2 and 3). From 1987 to 1992, 3 states showed no net change, 6 states increased erosion rates from 3.4 to 18.5 %, and 41 states reduced erosion rates from 2.2 to 48.5 %. The net result over the 1982 to 1992 period showed 4 states with no change, 4 states with increased sheet and rill erosion, led by Connecticut with a 27.7% increase, and 42 states with decreased erosion ranging from 4.0% to a high of 38.5% for Missouri. There were some rather

**Table 2.** Cropland sheet and rill erosion rate and change in erosion rate by state arranged by decreasing erosion rate for 1982.

| State          | Year                                   |      |      | Period |       |       |
|----------------|--|------|------|--------|-------|-------|
|                | 1982                                   | 1987 | 1992 | 87-82  | 92-87 | 92-82 |
|                | tons ac <sup>-1</sup> yr <sup>-1</sup> |      |      |        |       |       |
| Tennessee      | 11.0                                   | 11.0 | 9.3  | 0.0    | -15.5 | -15.5 |
| Caribbean      | 11.0                                   | 10.8 | 12.8 | -1.8   | 18.5  | 16.4  |
| Missouri       | 10.9                                   | 8.5  | 6.7  | -22.0  | -21.2 | -38.5 |
| Kentucky       | 10.6                                   | 11.3 | 7.3  | 6.6    | -35.4 | -31.1 |
| Iowa           | 7.8                                    | 6.5  | 5.6  | -16.7  | -13.8 | -28.2 |
| Mississippi    | 7.7                                    | 6.7  | 5.7  | -13.0  | -14.9 | -26.0 |
| W. Virginia    | 7.7                                    | 10.1 | 5.2  | 31.2   | -48.5 | -32.5 |
| Alabama        | 7.6                                    | 6.4  | 6.9  | -15.8  | 7.8   | -9.2  |
| Pennsylvania   | 7.5                                    | 7.7  | 6.4  | 2.7    | -16.9 | -14.7 |
| Virginia       | 7.2                                    | 6.9  | 6.6  | -4.2   | -4.3  | -8.3  |
| New Jersey     | 7.1                                    | 7.2  | 5.8  | 1.4    | -19.4 | -18.3 |
| North Carolina | 6.5                                    | 6.3  | 5.6  | -3.1   | -11.1 | -13.8 |
| Illinois       | 6.4                                    | 5.3  | 4.4  | -17.2  | -17.0 | -31.3 |
| Georgia        | 6.3                                    | 6.2  | 5.5  | -1.6   | -11.3 | -12.7 |
| Rhode Island   | 6.2                                    | 6.1  | 5.8  | -1.6   | -4.9  | -6.5  |
| Washington     | 6.1                                    | 7.1  | 5.1  | 16.4   | -28.2 | -16.4 |
| Maryland       | 5.6                                    | 5.2  | 4.9  | -7.1   | -5.8  | -12.5 |
| Oregon         | 5.5                                    | 3.9  | 3.9  | -29.1  | 0.0   | -29.1 |
| Massachusetts  | 5.4                                    | 5.7  | 4.2  | 5.6    | -26.3 | -22.2 |
| Idaho          | 5.4                                    | 4.8  | 3.7  | -11.1  | -22.9 | -31.5 |
| Wisconsin      | 5.2                                    | 4.6  | 4.1  | -11.5  | -10.9 | -21.2 |
| Hawaii         | 5.0                                    | 5.1  | 4.6  | 2.0    | -9.8  | -8.0  |
| Nebraska       | 4.9                                    | 4.3  | 3.6  | -12.2  | -16.3 | -26.5 |
| Indiana        | 4.8                                    | 4.4  | 3.4  | -8.3   | -22.7 | -29.2 |
| Louisiana      | 4.8                                    | 4.2  | 3.6  | -12.5  | -14.3 | -25.0 |
| Connecticut    | 4.7                                    | 5.8  | 6.0  | 23.4   | 3.4   | 27.7  |
| New Hampshire  | 4.6                                    | 5.0  | 3.6  | 8.7    | -28.0 | -21.7 |
| Vermont        | 4.6                                    | 4.3  | 4.2  | -6.5   | -2.3  | -8.7  |
| New York       | 4.3                                    | 4.5  | 4.4  | 4.7    | -2.2  | 2.3   |
| Maine          | 4.3                                    | 4.4  | 3.1  | 2.3    | -29.5 | -27.9 |
| South Carolina | 4.0                                    | 4.0  | 3.3  | 0.0    | -17.5 | -17.5 |
| Ohio           | 3.9                                    | 3.7  | 3.3  | -5.1   | -10.8 | -15.4 |
| Arkansas       | 3.8                                    | 3.8  | 3.5  | 0.0    | -7.9  | -7.9  |
| South Dakota   | 2.9                                    | 2.6  | 2.3  | -10.3  | -11.5 | -20.7 |
| Oklahoma       | 2.7                                    | 3.0  | 3.0  | 11.1   | 0.0   | 11.1  |

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**Table 2.** Continued

| State      | Year |      | 87-82 | Period                                 |       |       |
|------------|------|------|-------|--|-------|-------|
|            | 1982 | 1987 |       | tons ac <sup>-1</sup> yr <sup>-1</sup> | 92-87 | 92-82 |
| Kansas     | 2.6  | 2.6  | 2.3   | 0.0                                    | -11.5 | -11.5 |
| Texas      | 2.6  | 2.5  | 2.6   | -3.8                                   | 4.0   | 0.0   |
| Minnesota  | 2.6  | 2.6  | 2.4   | 0.0                                    | -7.7  | -7.7  |
| Colorado   | 2.5  | 2.5  | 2.4   | 0.0                                    | -4.0  | -4.0  |
| Florida    | 2.4  | 2.1  | 1.8   | -12.5                                  | -14.3 | -25.0 |
| Montana    | 2.1  | 2.4  | 2.0   | 14.3                                   | -16.7 | -4.8  |
| Delaware   | 2.1  | 2.0  | 2.1   | -4.8                                   | 5.0   | 0.0   |
| N. Dakota  | 1.9  | 2.0  | 1.5   | 5.3                                    | -25.0 | -21.1 |
| Utah       | 1.7  | 2.2  | 1.7   | 29.4                                   | -22.7 | 0.0   |
| Wyoming    | 1.7  | 1.6  | 1.5   | -5.9                                   | -6.3  | -11.8 |
| California | 1.3  | 1.1  | 1.0   | -15.4                                  | -9.1  | -23.1 |
| N. Mexico  | 1.3  | 0.9  | 1.0   | -30.8                                  | 11.1  | -23.1 |
| Arizona    | 0.6  | 0.6  | 0.6   | 0.0                                    | 0.0   | 0.0   |
| Nevada     | 0.3  | 0.3  | 0.2   | 0.0                                    | -33.3 | -33.3 |
| Total US   | 4.5  | 4.1  | 3.5   | -8.9                                   | -14.6 | -22.2 |

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**Table 3.** Pattern of change in sheet and rill erosion by state for the periods 1982-1987 and 1987-1992.

| Change in erosion<br>for the period<br>1982-1987 |          | 1987-1992  | States in Category             |
|--|----------|--|--------------------------------|
| None   | None     | AZ   |                                |
| None   | Increase | None Decrease  | AK, CO, KS, MI, MN, NV, TN, SC |
| Increase   | None     | OK   |                                |
| Increase   | Increase | CT   |                                |
| Increase   | Decrease | HA, KY, MA, ME, MT, NH, NJ, NY, ND, PA, UT, WA, WV                             |                                |
| Decrease   | None     | OR   |                                |
| Decrease   | Increase | AL, DE, NM, TX, CARIBBEAN  |                                |
| Decrease   | Decrease | CA, FL, GA, ID, IL, IN, IA, LA, MD, MS, MO, NE, NC, OH, RI, SD, VT, VA, WI, WY |                                |

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Source: 1992 NRI.

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dramatic patterns of change in erosion. For example, West Virginia had a net increase in sheet and rill erosion of 31.2% from 1982 to 1987 and a net decrease of 48.5% from 1987 to 1992. Similar large fluctuations occurred for Montana, Utah, and Washington. However, these fluctuations are not readily explained without more detailed analysis and integration of NRI data with other information sources such as status of state conservation programs and changes in institutional arrangements.

The relative ranking of states by sheet and rill erosion rate changed slightly. However, 14 of the highest eroding 15 states in 1982 remained in the top 15 in 1992, with Illinois dropping from 13th to 19th and Connecticut increasing from 26th to 8th. For the 1992 top 15 eroding states, only the Caribbean and Connecticut showed increased sheet and rill erosion rates from 1982 to 1992.

Wind erosion was significant ( $> 2 \text{ tons ac}^{-1} \text{ yr}^{-1}$ ) in 18 states, with no wind erosion reported for 23 states and  $< 2 \text{ tons ac}^{-1} \text{ yr}^{-1}$  for 9 states in 1982 (Table 4). For the period 1982-1987, all but 4 of the highest wind eroding states increased wind erosion rates and there was no net change nationally. During the 1987-1992 period, 5 states had increased wind erosion rates, one state, Utah, had no net change. The net effect for the 1982-1992 period was for 7 states to show a net increase in wind erosion, of which 3 states, Nevada, Wyoming, and New Mexico, had the highest wind erosion rates in all three years. The fluctuations in wind erosion rates were large, from very large increases in Arizona and Nevada, to very large decreases in North Dakota, Iowa, and South Dakota. It is also somewhat

surprising that wind erosion increased in a state like Minnesota, which is adjacent to the very 3 states that showed the largest decreases in wind erosion.

From this discussion, we might conclude the following: soil erosion by wind and sheet and rill erosion by water declined nationally, however, erosion increased or remained unchanged in certain regions in the United States, fluctuations in erosion rates were dramatically large in places, and most of the erosion changes occurred primarily on cultivated cropland. The important question is what might have caused these changes to occur.

### What Caused the Changes?

Over the period of the three NRI's, a number of conservation programs, both state and national, should have had an impact on the rate of soil erosion in the United States. We will discuss three general categories of activities that could have had an impact on soil erosion rates: (1) the conversion of land to less erosive uses, including such things as the Conservation Reserve Program (CRP), (2) the implementation of on-land conservation practices, including conservation tillage, improved cropping systems, and other conservation practices (structures, etc.), and (3) a change in methods or procedures used in the NRI or differences in their application or interpretation from survey to survey. We will focus on the first two categories, as they can be addressed through analysis of the NRI data set. The third category is really beyond the scope of this paper. However, it could potentially be important, as it deals with the question as to whether the observed

**Table 4.** Wind erosion rates and their change from 1982 to 1992 for states with wind erosion rates exceeding 2 tons acre<sup>-1</sup> year<sup>-1</sup> for cultivated cropland.

| State        | Year                                   |      | Change |       |          |
|--------------|--|------|--------|-------|----------|
|              | 1982                                   | 1987 | 1992   | 87-82 | 92-87    |
|              | tons ac <sup>-1</sup> yr <sup>-1</sup> |      |        |       | Change % |
| Nevada       | 34.1                                   | 63.5 | 50.2   | 86.2  | -20.9    |
| Wyoming      | 16.4                                   | 16.7 | 21.3   | 1.8   | 27.5     |
| New Mexico   | 14.9                                   | 16.2 | 17     | 8.7   | 4.9      |
| Colorado     | 13.3                                   | 13   | 11.5   | -2.2  | -11.5    |
| Texas        | 12.6                                   | 11.5 | 9.2    | -8.7  | -20.0    |
| Montana      | 8                                      | 8.8  | 7.3    | 10.0  | -17.1    |
| Arizona      | 6.6                                    | 10.6 | 15.6   | 60.6  | 47.2     |
| Utah         | 6.6                                    | 7    | 7      | 6.1   | 0.0      |
| North Dakota | 6.4                                    | 6.5  | 2.1    | 1.6   | -67.7    |
| Minnesota    | 5.9                                    | 6.6  | 6.3    | 11.9  | -4.6     |
| Idaho        | 4.2                                    | 4.9  | 5.2    | 16.7  | 6.1      |
| South Dakota | 4.1                                    | 3.7  | 2.7    | -9.8  | -27.0    |
| Washington   | 3.7                                    | 3.8  | 5.3    | 2.7   | 39.5     |
| Iowa         | 3.1                                    | 2.4  | 1.4    | -22.6 | -41.7    |
| Michigan     | 2.6                                    | 2.9  | 2.6    | 11.5  | -10.3    |
| Kansas       | 2.6                                    | 3.1  | 2.1    | 19.2  | -32.3    |
| Oklahoma     | 2.4                                    | 2.6  | 1.8    | 8.3   | -30.8    |
| Oregon       | 2.2                                    | 2.5  | 1.7    | 13.6  | -32.0    |
| Total (U.S.) | 3.7                                    | 3.7  | 2.9    | 0.0   | -21.6    |

Source: 1992 NRI.

changes are real. Suffice it to say that it is the responsibility of the managers of the NRI to ensure the integrity and validity of the data contained therein. This will require a complete public documentation of the changes in methods, procedures, interpretations, etc. that form the basis for the NRI data.

### Soil Erosion and Land Conversion

While land use changes are not the focus of this analysis, shifts in land use can have considerable influence on soil erosion rates. This is particularly true over the period of consideration because 34 million acres of land in cropland in 1982 were idled under the Conservation Reserve Program (CRP) as of 1992. The general summary of land use of non-

federal rural land in the United States (Table 5) shows a decline of 4 million acres of total rural land, a reduction of 3.7% in cropland, and an increase of other land from 3.8 to 9.2% of non-federal rural land from 1982 to 1992. Thus, what appeared to be a very stable cropland base from 1967 to 1987 was reduced, primarily by CRP. What, then, was the effect of CRP and other land use shifts on the erosion rates from 1982 to 1992?

**Table 5.** Use of non-federal rural land (%) 1967-1992 (Source 1992 NRI, National Research Council, 1986, p. 5).

| Land Use            | 1967 | 1977 | 1982 | 1987 | 1992 |
|---------------------|------|------|------|------|------|
| (millions of acres) |      |      |      |      |      |
| Cropland            | 29.9 | 29.5 | 29.9 | 29.3 | 26.2 |
| Pastureland         | 35.2 | 9.5  | 9.4  | 9.2  | 9.1  |
| Rangeland           | -    | 29.1 | 29.0 | 29.0 | 28.9 |
| Forestland          | 30.9 | 26.4 | 28.0 | 28.5 | 28.6 |
| Other Land          | 4.0  | 5.5  | 3.8  | 4.8  | 9.2  |
| Total Rural Land    | 1506 | 1500 | 1487 | 1485 | 1483 |

Pastureland in 1967 included rangeland.

The effect of cropland conversion on soil erosion is illustrated for a national summary in Tables 6 and 7. Of the 31.8 million acres of CRP land in 1992, 16.5 million acres (51.8%) came from cropland classified as highly erodible cropland (HEL) in 1982. This portion of the CRP land removed 16.2% of HEL cropland from production, lowering the average sheet and rill erosion rate for cropland in this category from 8.9 to 0.9 tons ac<sup>-1</sup> yr<sup>-1</sup>, which corresponds to a reduction of 127 million tons of eroded soil. There were

14.5 million acres of HEL land converted to noncultivated cropland and other uses, lowering the average sheet and rill erosion rate from 10.3 and 12.2 to 2.3 and 1.0 tons ac<sup>-1</sup> yr<sup>-1</sup>, respectively, corresponding to a reduction of 141 million tons yr<sup>-1</sup> of eroded soil, 14 million tons more than CRP. Approximately 69.5% of HEL cropland in 1982 remained in cropland in 1992, but the average sheet and rill erosion rate decreased from 8.4 to 6.7 tons ac<sup>-1</sup> yr<sup>-1</sup> due to improved conservation, corresponding to a reduction of 120 million tons yr<sup>-1</sup> of eroded soil. The corresponding reductions in wind eroded soil were 155, 40, and 78 million tons yr<sup>-1</sup>, respectively, for CRP, non-cultivated cropland plus other, and cropland uses. Changes in 1982 HEL cropland resulted in a total erosion reduction of 661 million tons yr<sup>-1</sup> of soil. For sheet and rill and wind erosion, respectively, CRP accounted for 32.0 and 58.6 %, shift in land use 35.4 and 15.1% of this change, and changes in conservation measures 30.3 and 29.4% (Table 7). That a large portion of the changes in cropland came from non-erosive land is clearly demonstrated in Figure 1 which shows that a majority of cropland conversion between 1982 and 1992 was in the low erosivity index (EI) lands for both sheet and rill erosion (73.2%) and wind erosion (74.4%).

For cultivated non-HEL cropland, CRP removed 13.7 million acres (43%) from production. This portion of the CRP land removed 5.2% of the non-HEL cropland from production, with a corresponding decrease of 37 and 47 million tons yr<sup>-1</sup> eroded soil from sheet and rill and wind erosion, respectively. This was considerably less than the erosion reductions due to on-land conservation

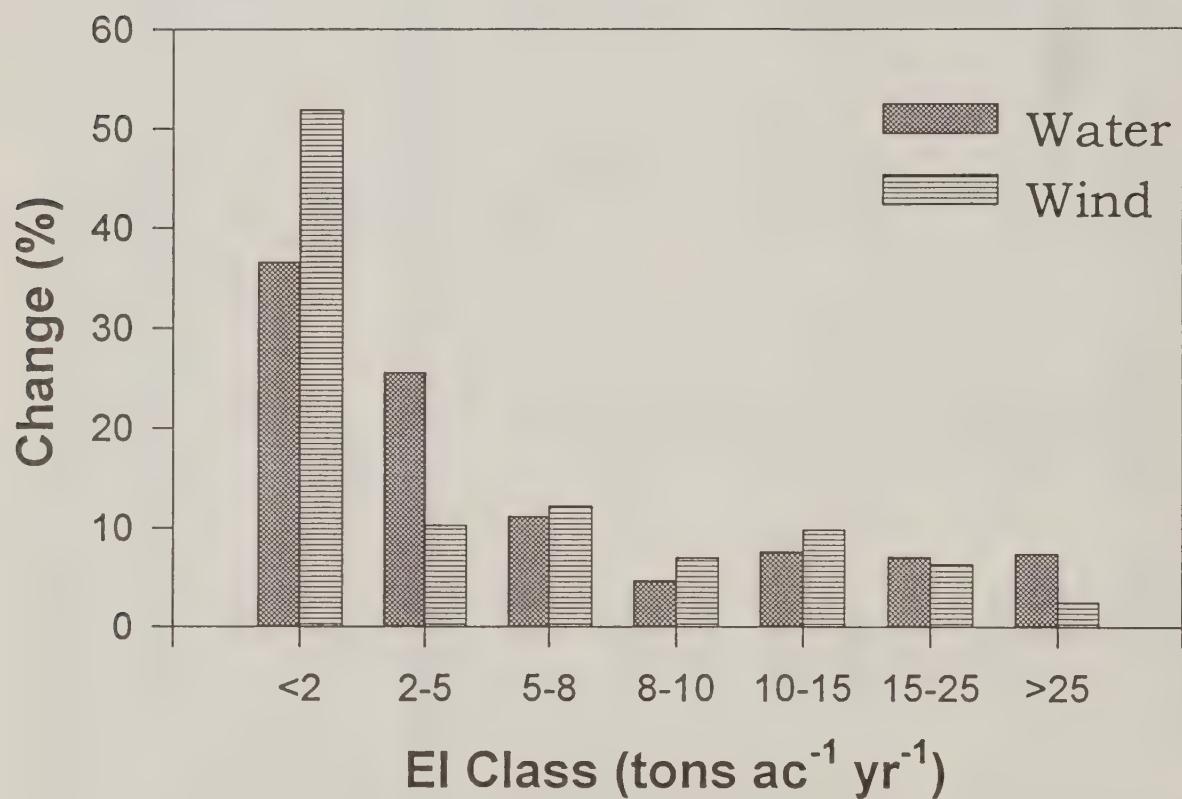
**Table 6.** Change in land use and associated change in erosion rate in 1992 by cropland use in 1982 (Source 1992 NRI).

| 1982 Cover/use   | Category     | Cultivated | 1992 Cover/Use Cropland |          |         | Total   |
|--|--------------|------------|-------------------------|----------|---------|---------|
|  |              |            | Noncultivated           | CRP Land | Other   |         |
| Cultivated Cropland<br>Highly Erodible<br>(EI > 8)     | Acres (1000) | 70734      | 6984                    | 16489    | 7558    | 101765  |
| % total  | 69.5         | 6.9        | 16.2                    | 7.4      | 100.0   |         |
| 1982 USLE  | 8.4          | 10.3       | 8.6                     | 12.2     | 8.9     |         |
| 1992 USLE  | 6.7          | 2.3        | 0.9                     | 1.0      | 5.0     |         |
| 1982 WEQ   | 7.8          | 3.9        | 10.7                    | 4.1      | 7.7     |         |
| 1992 WEQ   | 6.7          | 1.1        | 1.3                     | 1.4      | 5.1     |         |
| Cultivated Cropland<br>Not Highly Erodible<br>(EI < 8) | Acres (1000) | 225230     | 11536                   | 13692    | 13978   | 264436  |
| 1982 USLE  | 2.8          | 2.5        | 3.1                     | 3.0      | 2.8     |         |
| 1992 USLE  | 2.4          | 0.6        | 0.4                     | 0.4      | 2.1     |         |
| 1982 WEQ   | 2.2          | 1.5        | 3.6                     | 3.6      | 2.2     |         |
| 1992 WEQ   | 1.6          | 0.3        | 0.2                     | 0.2      | 1.4     |         |
| Noncultivated Cropland                                 | Acres (1000) | 14538      | 32212                   | 1636     | 6375    | 54761   |
| 1982 USLE  | 1.4          | 0.9        | 2.4                     | 1.0      | 1.1     |         |
| 1992 USLE  | 3.8          | 0.7        | 0.6                     | 0.6      | 1.5     |         |
| 1982 WEQ   | 0.7          | 0.4        | 0.9                     | 0.4      | 0.5     |         |
| 1992 WEQ   | 2.3          | 0.3        | 0.4                     | 0.3      | 0.8     |         |
| Other  | Acres (1000) | 14960      | 6124                    | 2224     | 1495744 | 1519052 |
| 1982 USLE  | 0.6          | 2.4        | 1.0                     | 0.6      | 0.6     |         |
| 1992 USLE  | 5.0          | 1.0        | 0.6                     | 0.5      | 0.6     |         |
| 1982 WEQ   | 1.2          | 0.6        | 1.2                     | 1.4      | 1.4     |         |
| 1992 WEQ   | 4.1          | 0.3        | 0.5                     | 1.3      | 1.3     |         |

**Table 7.** Total eroded soil and percentage of erosion change due by land use category in 1992 (Source 1992 NRI).

| 1982 Cover/use                  | Category | Total   |            | Cropland      |      | CRP  | Other |
|---------------------------------|----------|---------|------------|---------------|------|------|-------|
|                                 |          | Erosion | Cultivated | Noncultivated |      |      |       |
| tons/yr                         |          |         |            |               |      |      |       |
| Cultivated Cropland             | USLE     | 905709  | 30.3       | 14.1          | 32.0 | 21.3 |       |
| Highly Erodible (EI > 8)        | WEQ      | 783591  | 29.4       | 7.4           | 58.6 | 7.7  |       |
| Total                           |          | 1689299 | 29.9       | 11.0          | 44.3 | 15.0 |       |
| Cultivated Cropland             | USLE     | 740421  | 48.7       | 11.9          | 20.0 | 19.6 |       |
| not Highly Erodible<br>(EI < 8) | WEQ      | 581759  | 63.9       | 6.5           | 22.0 | 22.5 |       |
| Total                           |          | 1322180 | 55.4       | 9.5           | 20.9 | 20.9 |       |
| Total Cultivated Cropland       | Total    | 3011479 | 41.1       | 10.3          | 34.0 | 17.6 |       |

Figure 1. Distribution of the change in cropland (%) from 1982 to 1992 by EI class for water and wind erosion (Source 1992 NRI).



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practices and land conversion on non-HEL cropland, which reduced sheet and rill and wind erosion by 90 and 135 and 58 and 61 million tons  $\text{yr}^{-1}$ , respectively. Changes in 1982 non-HEL cropland resulted in a total erosion reduction of 397 million tons  $\text{yr}^{-1}$  of soil, of which, for sheet and rill and wind erosion, respectively, CRP accounted for 20.0 and 22.0%, land conversion 31.4 and 29.0%, and changes in conservation measures 48.7 and 63.9% (Table 7).

Land that was in non-cultivated cropland or other uses in 1992 that was converted to cropland in 1992 showed large increases in rates of both sheet and rill and wind erosion (Table 6). The average sheet and rill erosion rate increased from 1.4 to 3.8 and 0.6 to 5.0 tons  $\text{ac}^{-1} \text{ yr}^{-1}$ , respectively, for noncultivated cropland and other land, corresponding to an increase of 35 and 66 million tons  $\text{yr}^{-1}$  of eroded soil. The average wind erosion rate increased from 0.7 to 2.3 and 1.2 to 4.1 tons  $\text{ac}^{-1} \text{ yr}^{-1}$ , respectively, for noncultivated cropland and other land, corresponding to an increase of 23 and 43 million tons  $\text{yr}^{-1}$  of eroded soil. The conversion of land to cultivated cropland increased soil erosion 167 million tons  $\text{yr}^{-1}$  from 1982 to 1992. Thus, there is a flux of land use change that takes place annually that appears to go unnoticed relative to government programs on soil and water conservation. This illustrates the importance of accounting for conversion of land to cropland and demonstrates the potential fate of land returned to cropland from CRP as contracts begin to terminate in 1995.

From this discussion, it is apparent that CRP played an important role in reducing soil erosion rates but was not more important than other land use conversions and the implementation of on-land

conservation practices. Since a majority of CRP land came from the non-HEL cropland or other land uses, the impact of CRP was diminished relative to the initial intentions of the program. Further analysis will need to explore the relationship between timing of CRP contract and erosion impacts, since later CRP enrollments were focused on other natural resource agendas such as water quality. It would also be worthwhile to explore the reasons for cropland conversion since its impact on soil erosion was considerable. These issues need to be explored on a state or regional basis. From this point, we would like to explore what on-land changes took place that would have lead to the erosion reductions apparent in Table 6.

### **Soil Erosion and On-land Conservation Practices**

As indicated above, a significant reduction in soil erosion occurred on cultivated cropland, indicative of changes in on-land management practices. The product of the C and P factors of the USLE for cropland declined from 0.277 to 0.243. While crop rotations are important in determining both sheet and rill and wind erosion, a more in-depth analysis is needed to determine the extent to which changes in crop rotation affected soil erosion rates. The changes in irrigated land were small from 1982 through 1992, with a slight decrease in irrigated cultivated cropland and a slight increase in irrigated noncultivated cropland (Table 8). Therefore, on a national basis, changes in irrigation was not an important factor in the changes in soil erosion over this period. For this analysis, we chose to

**Table 8.** Changes in irrigated cropland from 1982 to 1992 (Source 1992 NRI).

| Year                     | Cultivated Cropland |         |         | Noncultivated Cropland |        |        |
|--------------------------|---------------------|---------|---------|------------------------|--------|--------|
|                          | Irrig.              | Non.    | Irrig.  | Irrig.                 | Non.   | Irrig. |
| ----- 1000's acres ----- |                     |         |         |                        |        |        |
| 1982                     | 48,169              | 318,031 | 366,200 | 13,575                 | 41,186 | 54,761 |
| 1987                     | 47,419              | 303,490 | 350,908 | 13,822                 | 41,916 | 55,738 |
| 1992                     | 47,685              | 277,777 | 325,462 | 14,503                 | 42,352 | 56,855 |

focus primarily on the role of conservation tillage in changing soil erosion rates.

### Conservation Tillage

Changes in conservation tillage should account for some of change in soil erosion rates, since conservation tillage, by definition, reduces soil erosion, primarily through the maintenance of crop residue cover. The only trend comparison possible in the 1992 NRI is category 329 that records if conservation tillage of any form is present or absent on the land. In 1992, more detailed information is available on which tillage system was used and whether sufficient residue cover was present on the soil surface. However, these data were not taken in earlier years of the NRI.

The use of conservation tillage by state according to NRI and the Conservation Technology Information Center (1,2), along with changes from 1982 to 1992, are given in Table 9. According to the NRI, there was a decline in conservation tillage in 28 states amounting to a net loss in

conservation tillage of 24.9 million acres and an increase in 19 states of 16.3 million acres. Three states - Connecticut, Rhode Island, and Nevada - stopped collecting data on conservation tillage. Thus, nationally, NRI estimates a reduction in the use of conservation tillage from 1982 to 1992 of 8.6 million acres. The largest acreage reductions occurred in states within the Great Plains, with the largest decreases occurring in Kansas, North Dakota, Nebraska, Texas, Mississippi, and Montana. The major increases (93.6%) came in 7 states in the Corn Belt - Iowa, Illinois, Ohio, Indiana, Wisconsin, Michigan, and Minnesota - with Iowa alone accounting for 50.7 % of the increase. Approximately 55% of Iowa's cropland in 1992 was in some form of conservation tillage, an increase of 149% over 1982. This increase in conservation tillage appears to be associated with the reductions in sheet and rill and wind erosion in Iowa from 1982 to 1992 (Tables 2 and 4). However, there was little correlation between sheet and rill erosion

**Table 9.** Distribution of conservation tillage acreage by state as estimated by the National Resources Inventory and the Conservation Technology Information Center (CTIC) in 1982 and 1992.

|               | NRI                  |       |            | CTIC |                      |            |
|---------------|----------------------|-------|------------|------|----------------------|------------|
|               | 1982                 | 1992  | Difference | 1982 | 1992                 | Difference |
|               | ---Acres (1000's)--- |       |            |      | ---Acres (1000's)--- |            |
| Alabama       | 180                  | 29    | -150       | -84  | 1602                 | 389        |
| Arizona       | 142                  | 33    | -110       | -77  | 381                  | 9          |
| Arkansas      | 251                  | 593   | 342        | 136  | 64                   | 644        |
| California    | 1364                 | 1174  | -190       | -14  | 11                   | 848        |
| Colorado      | 3800                 | 3030  | -770       | -20  | 44                   | 10         |
| Connecticut   | 2                    |       |            |      | 3033                 | 1061       |
| Delaware      | 349                  | 336   | -13        | -4   | 447                  | 335        |
| Florida       | 270                  | 146   | -124       | -46  | 140                  | 53         |
| Georgia       | 718                  | 445   | -273       | -38  | 655                  | 648        |
| Hawaii        | 11                   | 6     | -5         | -43  |                      | 3          |
| Idaho         | 1378                 | 1487  | 109        | 8    | 13651                | 9714       |
| Illinois      | 4648                 | 7053  | 2405       | 52   | 1132                 | 1038       |
| Indiana       | 2824                 | 4002  | 1177       | 42   | 11248                | 11163      |
| Iowa          | 5547                 | 13815 | 8267       | 149  | 4467                 | 4310       |
| Kansas        | 10096                | 5517  | -4579      | -45  | 11685                | 5353       |
| Kentucky      | 1662                 | 1604  | -58        | -4   | 2592                 | 2320       |
| Louisiana     | 132                  | 96    | -36        | -27  | 18                   | 564        |
| Maine         | 18                   | 36    | 18         | 105  | 3                    | 5          |
| Maryland      | 946                  | 930   | -16        | -2   | 1080                 | 832        |
| Massachusetts | 2                    | 2     | 0          | 0    | 125                  | 37         |
| Michigan      | 1030                 | 1509  | 479        | 47   | 884                  | 2248       |
| Minnesota     | 1642                 | 2095  | 453        | 28   | 3571                 | 4075       |

**Table 9. Continued**

|                      | 1982  | NRI<br>1992 | Difference | %   | 1982 | CTIC<br>1992 | Difference | %   |
|----------------------|-------|-------------|------------|-----|------|--------------|------------|-----|
| ---Acres (1000's)--- |       |             |            |     |      |              |            |     |
| Missouri             | 1833  | 1897        | 64         | 3   | 2097 | 1170         | -927       | -44 |
| Montana              | 5371  | 3560        | -1811      | -34 | 1556 | 2194         | 638        | 41  |
| Nebraska             | 7544  | 4349        | -3195      | -42 | 465  | 805          | 340        | 73  |
| Nevada               | 12    |             |            |     | 1089 | 5043         | 3954       | 363 |
| New Hampshire        | 6     | 1           | -5         | -84 | 6938 | 7570         | 632        | 9   |
| New Jersey           | 137   | 95          | -42        | -31 | 2    | 2            | 0          | 16  |
| New Mexico           | 551   | 344         | -207       | -38 | 90   | 122          | 32         | 36  |
| New York             | 228   | 87          | -141       | -62 | 676  | 266          | -410       | -61 |
| North Carolina       | 530   | 423         | -107       | -20 |      | 13           |            |     |
| North Dakota         | 4976  | 1046        | -3929      | -79 | 297  | 420          | 123        | 41  |
| Ohio                 | 1068  | 2803        | 1735       | 163 | 3462 | 3811         | 349        | 10  |
| Oklahoma             | 5026  | 3700        | -1326      | -26 | 2524 | 1911         | -612       | -24 |
| Oregon               | 812   | 871         | 59         | 7   | 608  | 434          | -174       | -29 |
| Pennsylvania         | 496   | 771         | 275        | 55  | 691  | 1031         | 341        | 49  |
| Puerto Rico          | 50    | 68          | 18         | 37  |      | 19           | 19         |     |
| Rhode Island         | 1     |             |            |     | 0    | 380          | 380        |     |
| Sout Carolina        | 111   | 133         | 22         | 20  | 522  | 200          | -323       | -62 |
| South Dakota         | 3622  | 2498        | -1124      | -31 | 3285 | 4251         | 967        | 29  |
| Texas                | 11466 | 8999        | -2467      | -22 | 2324 | 1526         | -798       | -34 |
| Tennessee            | 497   | 618         | 122        | 25  | 3199 | 4077         | 877        | 27  |
| Utah                 | 380   | 92          | -289       | -76 | 43   | 114          | 71         | 166 |
| Vermont              | 7     | 9           | 2          | 24  | 1300 | 818          | -482       | -37 |
| Virginia             | 863   | 394         | -469       | -54 | 15   | 5            | -10        | -67 |
| Washington           | 2158  | 527         | -1631      | -76 | 510  | 714          | 204        | 40  |
| West Virginia        | 50    | 63          | 13         | 26  | 1325 | 1751         | 425        | 32  |
| Wisconsin            | 527   | 1263        | 736        | 140 | 62   | 56           | -6         | -9  |
| Wyoming              | 222   | 191         | -31        | -14 | 13   | 117          | 104        | 796 |

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rate and change in erosion from 1982 to 1992 (regressions not shown). For other states, large reductions in conservation tillage were observed with dramatic decreases in soil erosion rates. For example, for North Dakota, NRI estimates a 79% reduction in conservation tillage but a 25.0 and a 67.2% reduction in sheet and rill and wind erosion rates, respectively. The fact that most of the CRP acreage is in the Great Plains may explain these observations.

The NRI estimates do not correspond well with CTIC estimates of conservation tillage (Table 9). A strong relationship should be present because both should estimate large and small acreages. However, the coefficient of variation for the regressions of NRI estimates on CTIC estimates were 0.47 and 0.68 for 1982 and 1992, respectively (Figure 2 a,b). The general trend was for a decrease in conservation tillage for both NRI and CTIC estimates (Figure 3 a,b). However, there was no correlation between changes in conservation tillage from 1982 to 1992 estimated in the NRI with those reported by CTIC (Figure 4). There are no obvious reasons for the differences in estimates, particularly since tillage definitions for both NRI and CTIC should have followed SCS guidelines. However, some of differences between years is expected due to definitional changes between 1982 and 1992.

Of the land brought into conservation tillage in 1992 that was not in conservation tillage in 1982, 32.1 % was classified as highly erodible (erodibility index (EI) > 8) (Figure 5), although the percentage varied by state over the range 0 to 100% (Figure 6). The national percentage is similar to the 33.3 % of all land in

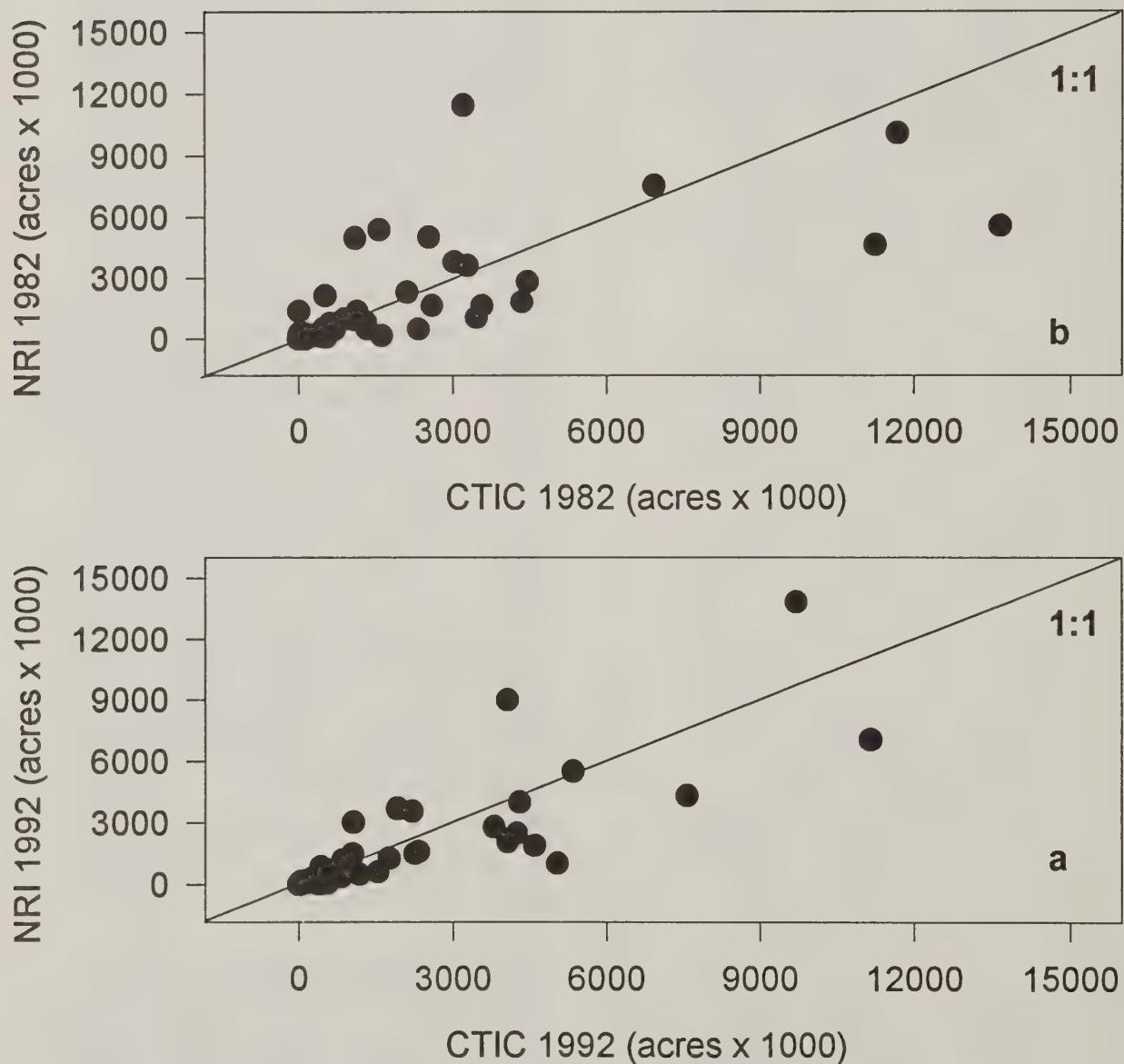
conservation tillage in 1982 that was highly erodible. For the 7 states in the Corn Belt that accounted for most of the increase in conservation tillage in from 1982 to 1992, generally, with the exception of Wisconsin (48%), a smaller portion of adoption occurred on highly erodible soil in Iowa (26%), Illinois (21%), Ohio (17%), Indiana (220%), Michigan (9%), and Minnesota (13%). The majority of conservation tillage adoption is taking place on lands with low erosion potential, indicating the adoption of conservation tillage is not driven by concern over soil erosion control.

We conclude from this discussion that conservation tillage has declined in many areas and, where it has increased, it has often been adopted on non-highly erodible land. Where conservation tillage has apparently declined, erosion rates have also declined. The lack of agreement between NRI and CTIC estimates of the occurrence of conservation tillage is disturbing. While the evidence suggests that conservation tillage may have contributed to erosion reduction in some areas, it does not account for a large portion of the erosion reductions indicated by the NRI. Therefore, the relationship between erosion changes and changes in conservation tillage are not clear and requires more detailed examination.

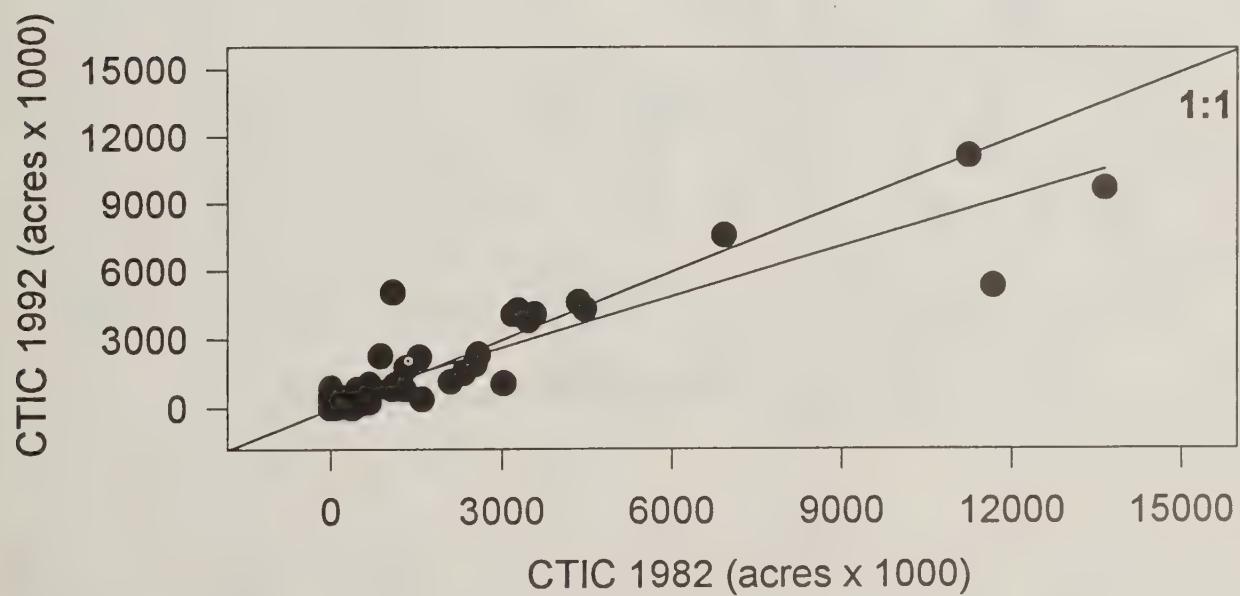
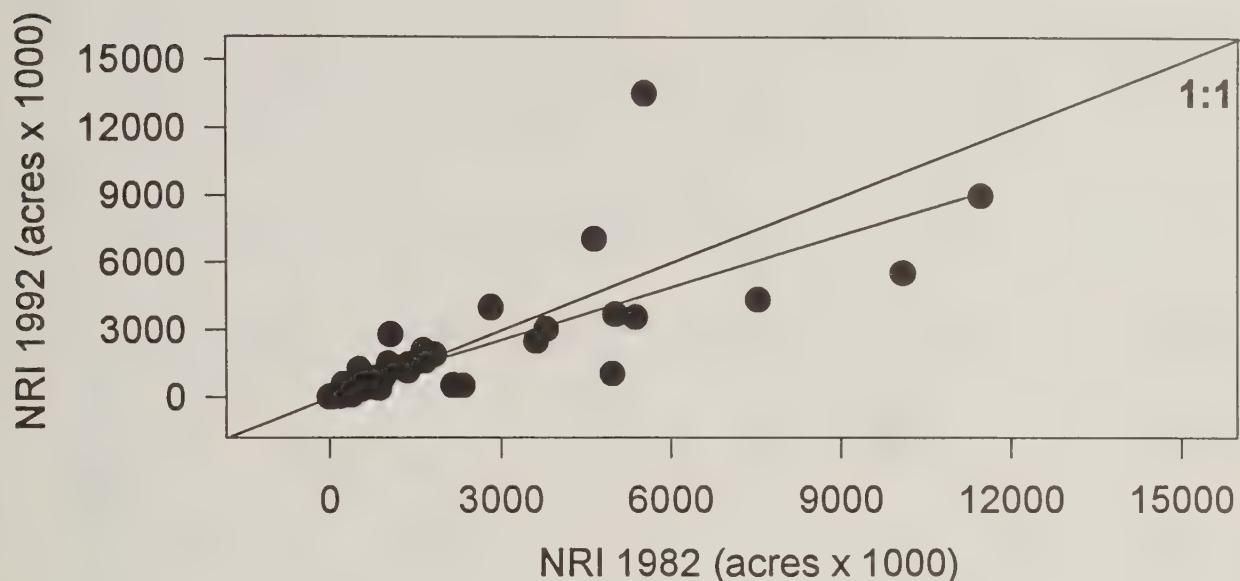
## Potential Impacts on Soil Quality

Since there are no direct measures of soil quality in the NRI, this is a significant limitation in the NRI data set. Therefore, only indirect measures of soil quality changes are possible in the NRI through modelling and linkage to soils data bases available with the 1992 NRI. Estimates of changes in soil productivity due to soil

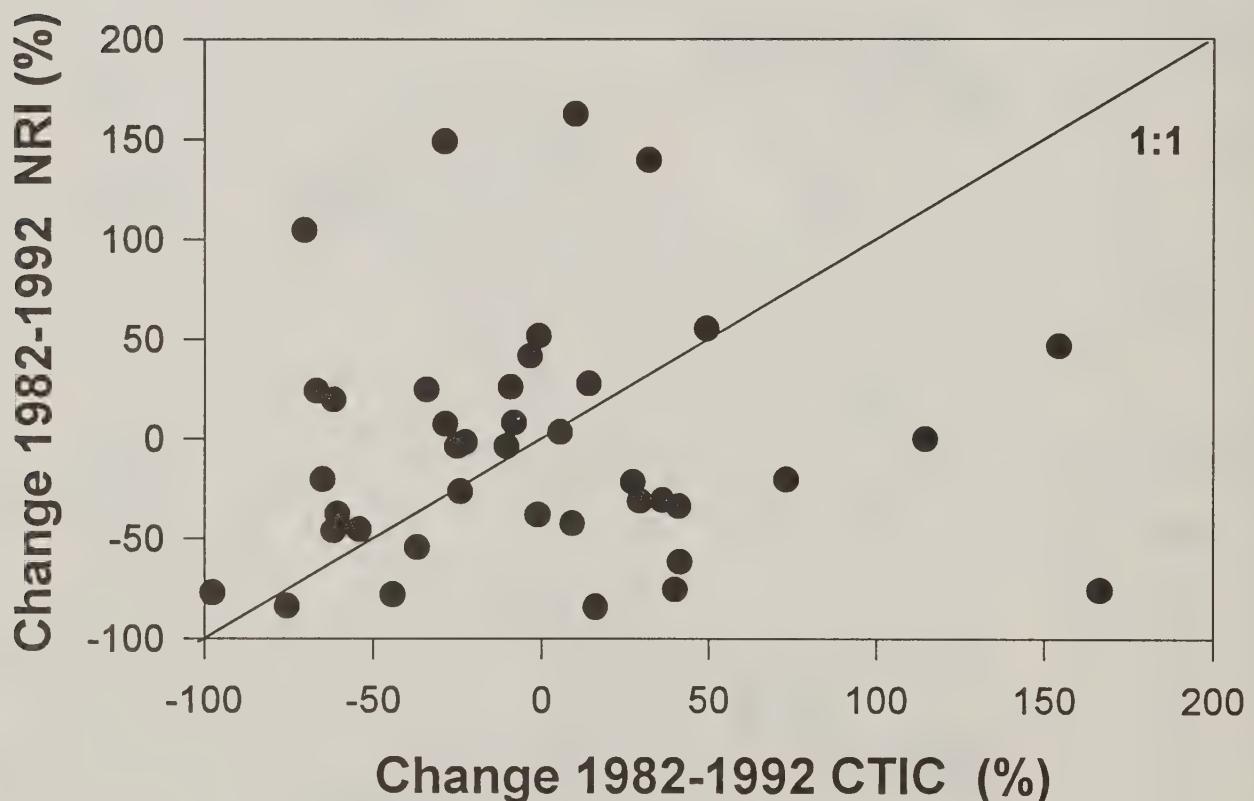
**Figure 2a and 2b.** Scatterplot of acres in conservation tillage estimated by the 1982 NRI and the Conservation Technology Information Center (CTIC) in (a) 1982 and (b) 1992 (Source 1992 NRI and CTIC, 1982, 1992).



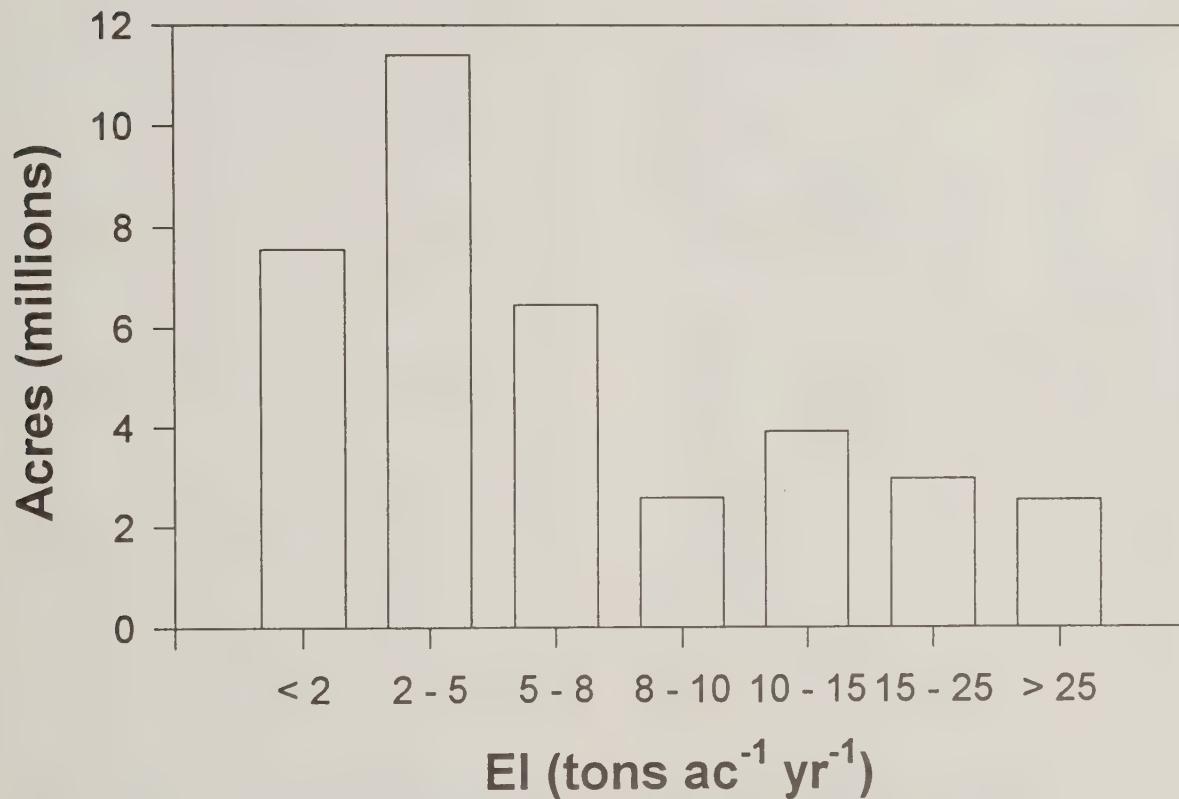
**Figure 3a and 3b.** Scatterplot of acres in conservation tillage in 1982 and 1992 estimated by (a) NRI and (b) the Conservation Technology Information Center (CTIC) (Source 1992 NRI and CTIC, 1982,1992).



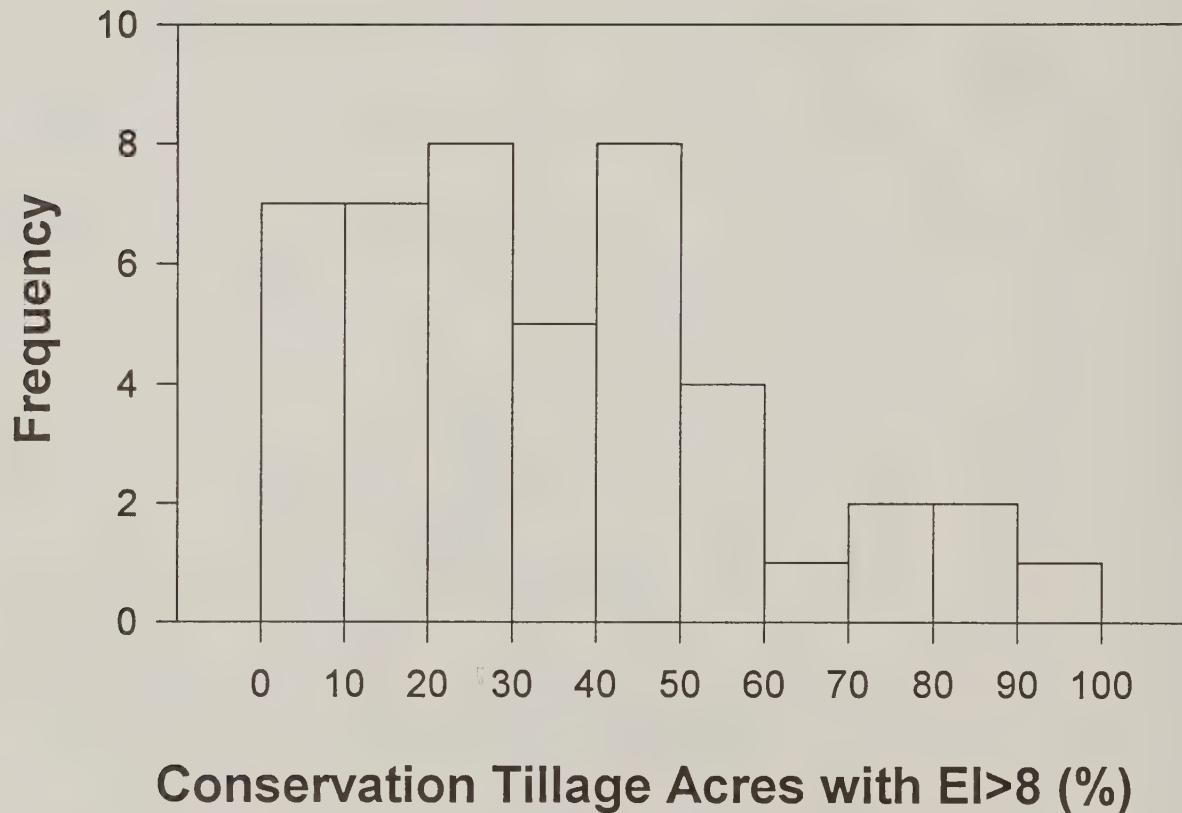
**Figure 4.** Scatterplot of the acreage change (%) in conservation tillage from 1982 to 1992 estimated by NRI and the Conservation Technology Information Center (CTIC) CTIC (Source 1992 NRI and CTIC, 1982,1992).



**Figure 5.** Distribution of acres that were in conservation tillage in 1992 but not in 1982 by EI class (Source 1992 NRI).



**Figure 6.** Frequency distribution of states as % of acres in conservation tillage with EI >8 (Source 1992 NRI).



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erosion were made in the RCA Appraisal (4), based on data in the 1982 NRI, national soils data bases, and the EPIC simulation model (5).

It may be tempting to assume that a reduced erosion rate should decrease the rate of soil degradation. While soil degradation is proportional to soil erosion rate, the rate of degradation per unit of eroded soil varies by soil type, making effects on soil quality site specific and, thus, not conducive to highly aggregated analysis. Additionally, on-land soil conservation practices in themselves can alter soil quality (e.g., crop rotations, conservation tillage). Therefore, analysis of the NRI relative to soil quality changes is needed, but requires an considerable effort beyond the scope of this paper.

### Summary and Recommendations

This initial analysis of the 1992 NRI and earlier data sets was to examine the impacts of erosion on soil quality. As noted in the last section, this type of analysis is not possible with highly aggregated national data where surrogate measures of soil quality must be developed. Nonetheless, in reaching this conclusion a number of other findings were reported that need additional analysis and examination.

The linear decrease in national sheet and rill erosion rates on cropland masks some dramatic shifts in erosion rates within states. The national decrease between 1987 and 1992 for wind erosion also masks some major changes within states. There are at least four potential sources for these fluctuations. State conservation programs could be one source of this variation. New programs, changes in program policy mechanisms, funding

and staffing of these programs and program features that optimize the ability to build from federal programs could all explain shifts in NRI figures from 1982 to 1992. A second potential source of variation are the agricultural markets and production technologies found within states. Shifts to new crops or products or the use of different production techniques within a state could introduce variation into the NRI data base across time. The third potential source of variation is associated with the SCS personnel assigned NRI responsibility within states. Shifts in personnel at key positions could change emphasis on NRI data collection efforts. Related to this is how the data was collected, i.e., rules for data collection, the shift from on-site to remote sensing methods, and the management of the primary data after collection could all introduce variation in the data set. The final source of variation is related to climatological patterns. Dramatic shifts in wind or water events within a state or region could also contribute to the observed patterns of variation. Regardless of the source, it is clear that additional attention needs to be given to explaining these state patterns embedded within national trends.

Although the 1990 farm bill shifted the focus of the CRP from primarily erosion control to that of water quality, the NRI does provide some unique insights on the impact of this national program. The relative contribution of the CRP to erosion control compared to other shifts in land use and technological change is not as significant as the publicity and costs surrounding the program. The CRP accounted for less than a third of the reduction in sheet and rill erosion rates on

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HEL cropland and just over half of the reduction in wind erosion rates. The effectiveness of the CRP has been discussed elsewhere (U.S. General Accounting Office, 1993, Conservation Reserve Program Effectiveness is Uncertain. GAO/RCED-93-132. GAO Resources, Community and Economic Development Division, Washington DC.) based on economic criteria.

As was the case with erosion rates, conservation tillage shifted between and within states across the NRI data collection efforts. These residue management systems have and continue to be promoted as a means to protect the resource base. Yet NRI data indicate that adoption of these residue systems is being driven by profitability and not conservation concerns. This conclusion is supported both by where the greatest increases in conservation tillage are occurring, and by the erosion potential of the lands on which it is applied. More troubling is the lack of confidence in knowing the actual acres under conservation tillage as evidenced by the poor correspondence between NRI and CTIC estimates. Both measurement efforts are under the jurisdiction of the same agency, but employ different methods, i.e., an inventory based on spatial sampling versus a "windshield" survey conducted by local personnel. While high correspondence may not be expected due to the different measurement protocols and changes in definitions, the fact there was no correlation between changes in conservation tillage from 1982 to 1992 as measured by these two different methods is difficult to explain. Also difficult to explain at the aggregate level are situations where both the acreage in

conservation tillage and erosion rates decreased significantly.

This was an aggregate analysis of the 1982-1992 NRI data set. As is often the case in such instances, the results point out the need for further detailed analysis. A number of data anomalies were reported that require additional investigation. A major function of this paper, coupled with the public access to the NRI data sets, is to identify issues needing further investigation. Hopefully this will follow. However, considering both the current as well as the future potential of the NRI to assess the condition of the U.S. natural resource base, to evaluate the effectiveness of both state and national programs, and to target areas and issues of high concern, we feel it is imperative that a more organized and continuing analysis of NRI data be instituted. Simply collecting the data and making it available for public analysis is not sufficient to achieve the above objectives. An ongoing, rigorous analysis of the NRI data will also identify issues associated with data collection, measurement and reporting that can be addressed prior to future NRI efforts. This "first look" at NRI trend data points out the importance and uniqueness of this data set for analyzing national trends. Yet it also emphasizes the need to enhance reliability and validity so as to increase confidence in the results.

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# Land Use Change 1982-92

Linda K. Lee\*

An important component of resource assessment is an analysis of land use change. The amount and quality of the nation's rural land base and the rate of rural land conversion to urban and developed uses have important implications for issues such as food production and export capabilities, wildlife habitat, and open space preservation. National Resources Inventories (NRI), comprehensive surveys of our nation's nonfederal land resources conducted every five years by the Soil Conservation Service (SCS), have helped to provide data to assess and understand the status of our nation's rural land base. However, procedural changes and improvements in survey techniques have made comparisons of land use estimates between surveys difficult (4). The 1992 National Resources Inventory was designed to be comparable with the 1987 and 1982 NRI, making a decade-long analysis possible. This paper presents a first look at the NRI data with respect to land use change and urbanization during the 1982-92 time period. Conversion of rural land to urban and developed uses, prime farmland and cropland changes are analyzed in this paper.

## Urbanization

The NRI data allow a unique look at conversion of rural land to urban and developed uses during the 1980s. Between 1982-92 developed land increased by almost 14 million acres (table 1). The estimated annual rate of change was 1.4 million acres. Developed land as defined by the 1992 NRI includes large tracts greater than 10 acres of residential,

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**Table 1. Changes in Developed Land, 1982-92**

|                | <u>Acres</u> |
|----------------|--------------|
| 1982           | 78,373,400   |
| 1992           | 92,352,400   |
| Change 1982-92 | 13,979,000   |
| Annual Change  | 1,397,900    |

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commercial, and other developed uses that meet definitional and density requirements. Small built-up tracts of .25-10 acres that meet definitional and density requirements are also included for the first time in 1992. Previously this category was included in minor or other land uses. Rural transportation uses such as highways, roads, railroads, and private roads outside urban areas are also part of this land use category. Table 2 indicates the distribution of developed land by subcategory.

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**Table 2. Developed Land by Subcategory, 1982-92**

|      | Large<br>Built-up | Small<br>Built-up | Roads      | Total<br>(Acres) |
|------|-------------------|-------------------|------------|------------------|
| 1982 | 47,380,000        | 4,516,900         | 26,476,500 | 78,373,400       |
| 1992 | 58,921,200        | 6,429,100         | 27,002,100 | 92,352,400       |

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A closer examination of the data reveals that gross conversions of rural land to developed land totaled 14.6 million acres (table 3). The net additions to developed land in Table 1 are slightly less because some developed land in 1982 reverted to other uses in 1992. Most of the conversions came from forestland,

about 38%. Another 28% came from 1982 cropland with the remaining conversions nationwide coming from pastureland and rangeland.

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**Table 3. Major Land Uses Converted to Developed Land, 1982-92**

|             | <u>% of Total<br/>Conversions</u> |
|-------------|-----------------------------------|
| Cropland    | 28.4                              |
| Pastureland | 16.8                              |
| Rangeland   | 14.5                              |
| Forestland  | 38.1                              |
| Other       | 2.2                               |
| Total Acres | 14,647,100                        |

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Regionally, conversions of rural land to developed land varied widely by state and region (table 4). The states with the highest rates of rural land converted to urban use in the 1982-92 time period were primarily in the South and West, with the exception of New Hampshire which led the nation in the rate of urbanization during the 1980s. The high rate of urbanization in New Hampshire was due in part to the relatively small urban base in the state. The Northeast in general did not rank high in rate of change in developed land, however, a relatively small rural and agricultural land base in this region makes continued losses to development important. The regional urbanization rates reflect demographic shifts in population to the South and West. Interest in conversion of rural land to developed and urban uses may expand to these regions if growth continues.

**Table 4. Top 10 States by Urbanization Rates, 1982-92**

|                | <u>% Increase</u> |
|----------------|-------------------|
| New Hampshire  | 36.96             |
| North Carolina | 36.19             |
| Arizona        | 35.14             |
| Florida        | 34.55             |
| Georgia        | 32.80             |
| Kentucky       | 28.63             |
| South Carolina | 28.14             |
| Nevada         | 26.46             |
| Virginia       | 25.71             |
| Tennessee      | 25.28             |

A major question with respect to urbanization is what is happening to the rate of urbanization. Increasing urbanization, in particular, suggests additional conversions of rural and agricultural land to developed uses. One way to monitor this trend is to look at the NRI data in the context of other urbanization estimates over time. This is difficult because definitions and procedures are not always consistent among studies or even previous NRIs. Comparisons are made with two groups of studies--historical NRI analyses and other urbanization studies.

#### *NRI analyses*

Table 5 summarizes some of the analyses of average annual expansion of urban acres that were conducted with NRI data. Comparisons are difficult among surveys because of procedural and definitional changes and survey improvements over time. Perhaps the most controversial estimate was the estimate of 3 million acres per year developed by the National Agricultural Lands Study (NALS) using data from the 1967 and 1977 NRIs (5). The 1977 NRI

estimate of urbanization was later officially acknowledged to be an overestimate due to procedural problems involving mapping materials, methods used to delineate urban areas, and inadequate quality control (4). A revised estimate using the improved 1982 NRI data suggested that less than a million acres per year were urbanized between 1967 and 1982 (6). NRI data from 1987 suggest that 800,000 acres per year were urbanized between 1982 and 1987 (6). The 1992 estimate, excluding small built-up areas which were not in previous estimates, suggested that 1.2 million acres per year were developed during the ten year period 1982-92, a slight increase from earlier estimates.

**Table 5. Estimates of U.S. Urbanization, NRI Data**

| Study                    | Time Period | Average Annual Expansion<br>(acres) |
|--------------------------|-------------|-------------------------------------|
| • NALS                   | 1967-1977   | 3,000,000                           |
| • Lee (5)                | 1967-1982   | 900,000                             |
| • NRI, 1987 (6)          | 1982-1987   | 800,000                             |
| • NRI, 1992 <sup>a</sup> | 1982-1992   | 1,206,680                           |

<sup>a</sup> Excludes small built-up acres

#### *Other Studies*

In addition to the NRI, other federal agencies monitor urbanization trends, although procedures and definitions vary due to different objectives (table 6). The U.S. Bureau of the Census, Geography Division has an historical data series which estimates urban area (2). The definition used by the Bureau of the Census is that an urban area has more than

2,500 population outside of an urbanized area and greater than 1,000 persons per square mile within an urbanized area. This excludes rural transportation and most small built-up areas. It could also include rural land within an urbanized area. Using the definition, the Bureau of the Census has estimated average annual expansion in urban areas to be 1.3 million acres per year during the 1970s and approximately 900,000 acres per year during the 1980s.

**Table 6. Average Annual Expansion in Urban Areas**

| Study                   | Time Period | Acres             |
|-------------------------|-------------|-------------------|
| Bureau of the Census    | 1970-80     | 1,276,000         |
| Air Photos, ERS         | 1970-80     | 740,000-1,000,000 |
| Major Uses of Land, ERS | 1980-87     | 1,333,000         |
| Bureau of the Census    | 1980-90     | 900,000           |

The Economic Research Service, USDA, has also periodically monitored urbanization trends in the U.S. Major Uses of Land, an historical data series which includes urban area estimates, developed an 1980-87 estimate of 1.33 million acres per year of urban expansion (1). An 1970-80 aerial photography study by Vesterby, Heimlich, and Krupa updated an earlier 1976 ERS study by Zeimetz and others (7,8). The Vesterby, Heimlich, and Krupa study sampled data from 135 fast-growth counties accounting for 47 percent of the population increase in the United States in the 1970's. The study concluded

that between 1970 and 1980 740,000-1,000,000 acres per year were urbanized in the U.S. Taken together, these data, particularly the Census data, suggest that urbanization rates have not increased in the U.S., but may in fact be lower in the 1980s than they were in the 1970s.

Another measure of urbanization rates is the average annual urban land conversion per household. This can be derived by dividing the average annual expansion in urban areas by the average annual increase in household numbers from Census of Population estimates. Table 7 summarizes the household land conversion estimates for several recent studies. The ERS aerial photo study had the smallest estimate of .4-.6 acres/household while the 1992 NRI had the largest estimate of 1.25 acres per household. The discrepancies may be explained in part by procedural and definitional differences among studies. The ERS estimate was developed from a sample of fast-growth counties. The NRI estimate was based on a broader definition of urban area than the Census estimates as it included both small and larger built-up areas.

**Table 7. Estimated of Household Land Conversion**

| Study            | Time Period | Net Land Conversion |
|------------------|-------------|---------------------|
|                  |             | Acres/Household     |
| Air Photos ERS   | 1970-80     | 0.4-0.6             |
| Bureau of Census | 1970-80     | 0.7                 |
| Bureau of Census | 1980-90     | 0.8                 |
| 1992 NRI         | 1982-92     | 1.25                |

## Prime Farmland

During the 1982-92 decade 4.1 million acres of "prime" farmland converted to developed uses. Prime land is usually defined as land that is best suited for producing food and fiber and has selected physical characteristics that enhance crop yields. Prime farmland that is converted to urban and developed uses is unlikely under typical economic conditions to be used again for farmland. Almost 58% of all prime farmland, or 2.4 million acres, converted to developed uses during this time period was from cropland (table 8). Another 19% came from forestland and 18% from pastureland. Thus, of the 14.6 million acres of land converted to developed uses during the 1982-92 time period, 4.1 million acres came from cropland and 2.4 million acres were from prime cropland. Concern over lost prime farmland should not be limited to cropland, however, as local conditions vary and loss of prime pastureland and forestland can also be significant. Table 9 lists the 10 states with the highest rates of loss of prime farmland between 1982-92.

**Table 8. Conversion of Prime Farmland to Developed Uses, 1982-92**

| Land Use    | % of Conversions |
|-------------|------------------|
| Cropland    | 57.6             |
| Pastureland | 18.3             |
| Rangeland   | 3.6              |
| Forestland  | 19.4             |
| Other       | 1.1              |
| Total Acres | 4,064,100        |

**Table 9. Top 10 States for Prime Farmland Loss, 1982-92**

|                | <u>% Decline</u> |
|----------------|------------------|
| New Mexico     | 29.4             |
| New Jersey     | 12.5             |
| Arizona        | 11.6             |
| Massachusetts  | 9.6              |
| Nevada         | 8.3              |
| Rhode Island   | 8.1              |
| Connecticut    | 6.4              |
| North Carolina | 4.7              |
| New Hampshire  | 4.6              |
| California     | 4.6              |

## Cropland

Changes in cropland between 1982 and 1992 have been significant with a 9.2% net decline in cropland acreage. The cropland base has remained relatively constant in recent NRIs, but several factors have influenced the recent reduction in cropland acreage. On the supply side, productivity increases, regional shifts in competitiveness for agricultural commodities, and programs such as the Conservation Reserve have all contributed to reductions in cropland acres. Demand factors such as export demand for agricultural commodities were not sufficient to offset cropland losses.

Behind any net land use change estimate, is a more dynamic picture of cropland loss and gains. Tables 10 and 11 reflect the gross losses and additions to the cropland base during the 1980s. Almost 60 million acres, most of which was in the Conservation Reserve Program included in the minor land use category, converted from cropland to other uses. An

additional 21 million acres, however, converted to cropland during this same time period, primarily from pastureland and rangeland. Despite large losses of cropland to other uses, there remains a pool of land with the potential to convert to cropland if conditions warrant and economic incentives are appropriate. Table 12 lists the states with the largest declines in cropland, mostly in the South.

**Table 10. Gross Cropland Loss, 1982-92**

| <u>Conversions to:</u> | <u>% of Total</u> |
|------------------------|-------------------|
| Pastureland            | 24.8              |
| Rangeland              | 3.5               |
| Forestland             | 5.3               |
| Minor                  | 57.1              |
| Developed              | 6.9               |
| Water and Federal      | 2.4               |
| Total Acres            | 59,727,200        |

**Table 11. Gross Additions to Cropland, 1982-92**

| <u>Conversions from:</u> | <u>% of Total</u> |
|--------------------------|-------------------|
| Pastureland              | 56.0              |
| Rangeland                | 27.0              |
| Forestland               | 6.9               |
| Minor                    | 5.6               |
| Developed                | 1.2               |
| Water and Federal        | 3.3               |
| Total Acres              | 21,083,700        |

**Table 12. Top 10 States for Cropland Loss, 1982-92**

|                | <u>% Decline</u> |
|----------------|------------------|
| Alabama        | 30.2             |
| Mississippi    | 22.8             |
| New Mexico     | 21.6             |
| Georgia        | 21.2             |
| New Jersey     | 19.7             |
| South Carolina | 16.7             |
| West Virginia  | 16.3             |
| Florida        | 15.9             |
| Colorado       | 15.7             |
| Texas          | 15.2             |

## Conclusions

Estimates of increases in developed land from the 1992 NRI appear generally consistent with estimates from other data sources. The NRI estimates appear higher than other estimates in terms of acres/year converted and net conversion/household. However, there are numerous definitional and procedural differences between the various urbanization studies. If small built-up areas are excluded from the analysis, the NRI estimates appear very consistent with other analyses. Overall, there is little evidence of increasing urbanization at the national level; urbanization rates appear to be stable or declining slightly.

There continues to be a decline in the number of prime farmland acres nationally. During the 1982-92 time period approximately 4 million acres of prime farmland converted to developed uses. Of this acreage, approximately 2 million acres were from prime cropland. Urbanization and loss of prime farmland and prime cropland continue to be a concern in some areas. Additional

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analysis is needed on this issue at the state and local level.

Cropland declines were significant during the NRI study period. There is now a large potential cropland base in pasture and the Conservation Reserve that can return to cropland under the right economic conditions. Forestlands could also be converted.

This analysis is a first look at the land use data from the NRI. The issues of urbanization, prime farmland, and cropland availability need to be explored in more detail and the state and regional level. From this initial analysis, it is apparent the 1992 NRI will provide a valuable look at the 1980s and rural, nonfederal land use change.

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# Wetlands: Data from the NRI

By Ralph E. Heimlich\*

My task in this paper is to discuss wetlands data in the National Resources Inventories and illustrate how that data can be used to address policy questions associated with wetlands. Most of this paper draws on previous work with earlier NRI data sets, but some limited data from the 1992 NRI is also presented here for the first time. I conclude with some recommendations for further enhancing NRI data collection and dissemination.

## Wetland Policy Analysis

Before launching into the data, some background on appropriate and inappropriate uses of the NRI data sets, as I see them, is in order. Criteria for what is appropriate and inappropriate hinge on the scope and objectives of the analysis undertaken.

## Scope

By scope, I mean the geographic coverage and associated resolution with which the answers to questions posed can meaningfully be addressed. Most of my work has been at a broad national or multi-state regional level at which information is needed to assess or evaluate proposed or implemented policies and programs. NRI data is perfect for analysis at this scale because it is a sample carefully drawn to be representative of conditions on the land at given points in time. Despite advances in computer speed and storage technology, a "wall-to-wall" analysis of wetlands at the national or regional level is probably still not feasible. The task becomes nearly impossible if, as is uniformly the case in Washington, the analysis must be done quickly and within limited budgets. Moreover, even if a "wall-to-wall" study could be

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accomplished, it is doubtful that the additional comprehensiveness and resolution would change the conclusions sufficiently to justify the additional cost and time required. NRI data is critical for this national analysis because it makes quick, inexpensive analyses feasible and because of the relative dearth of available data at this scale.

As the scope of analysis drops to smaller and smaller geographic units (state, multi-county, county, etc.) and the needed resolution or accuracy increase, the usefulness of sampled NRI data diminishes. Large scale (small area) studies require the comprehensive, high resolution data provided by remote sensing and digital orthophotography, augmented by sufficient field checks to insure ground truth and provide necessary on-ground interpretation. It is important to appreciate how inappropriate "wall-to-wall" techniques are to small scale (large area) studies, but just as important to acknowledge that sample techniques are generally inappropriate to large scale studies.

## Objectives

Analytical objectives usually change as scope changes. National or regional-level analyses usually focus on the extent, trend, and composition of resources, usually over fairly long periods of time. By contrast, local analyses are more often concerned with precise acreages, locations, characterizations, and landscape positions of resources. For example, assessing the amount, approximate cost, and regional distribution of land available for wetland restoration in a national reserve requires different data than identifying the best land to enroll in such a program in a given

county. NRI data, in conjunction with other secondary data sources, is admirably suited for the first question, but useless for the second one.

The objectives of the analysis are important in considering the statistical accuracy of estimates made from the NRI data. Confidence bands around point estimates from NRI depend on the variance in the variable and in the number of sample observations. Despite the fact that geocodes (county, major land resource area, hydrologic unit code) can be combined to map NRI estimates at sub-county units of geography, the sampling density is generally insufficient to narrow the confidence band around such a point estimate. Nevertheless, for most objectives of a national or regional analysis, it is useful to create such detailed maps in order to see spatial trends and patterns, but necessary to avoid putting much faith in the estimated value of a particular polygon in the map. With modern GIS technology, it is tempting to create such maps for smaller and smaller areas. However, the temptation to attribute greater accuracy at larger scales is harder to resist and more important to bear in mind given the usual objectives.

It is easy to see that NRI data are appropriately used in broad, national analyses and inappropriate for specific, local analyses, but difficult to judge how useful NRI data is away from the endpoints.

## Wetland Extent and Trends

Wetland policy analysis is confused by the fact that there are two important definitions of wetlands that bear an unclear relationship to each other. First, scientists defined wetlands as early as the 1950's for

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purposes of classification and management. Second, and more important from a policy standpoint, various agencies of the federal government define wetlands for jurisdictional purposes of regulatory, conservation, or restoration programs. By 1977, the four agencies involved in wetland programs (Corps of Engineers, Environmental Protection Agency (EPA), Fish and Wildlife Service (FWS), Soil Conservation Service (SCS)) agreed that wetlands are "areas that are inundated or saturated by surface or ground water at a frequency and duration sufficient to support, and that under normal circumstances do support, a prevalence of vegetation typically adapted for life in saturated soil conditions." However, there has been less agreement about what characteristics in the field can be used to delineate an area as wetlands according to one or another of Agency or Interagency Manuals for Identification and Delineation of Wetlands issued in 1987, 1989, or 1991.

Despite controversy over wetland delineation, several sets of more or less reliable data provide insight into overall trends. The earliest wetland inventories treated all wetlands the same, describing them with such terms as "swamp and overflowed lands". These terms were adequate when the object of the inventories was to quantify how much land was unfit for crop production without drainage efforts. As wildlife management became an object of wetland inventories, a management-based classification was adopted by the FWS and published in their Circular 39 (10). For the National Wetland Status and Trends Analysis, FWS commissioned the Cowardin system, a new classification system designed to capture ecologically

important differences and segregate dissimilar wildlife habitats that are geographically separated (1). Neither of the systems used for management or scientific wetland inventories precisely matches any of the jurisdictional wetland definitions used in regulatory programs. Thus, there has been no accurate, comprehensive accounting of wetlands subject to Section 404 or the swampbuster provisions. The 1992 inventory breaks new ground by reporting not only the Cowardin wetland system and subsystem, but wetland and exemption categories in support of the 1985 Food Security Act (see table 1). This is the first time that both scientific and jurisdictional wetland classifications have been available in one inventory.

A variety of estimates and inventories conducted over the years for various purposes have given us a fragmentary picture of the extent and trends in our wetland resources (figure 1). The FWS estimated from secondary sources that in 1780 there were 392 million acres of wetlands in what now constitute the 50 United States, and 221 million acres of wetlands in the lower 48 States. By 1980, only 274 million acres remained, with only 104 million acres in the lower 48 States. This amounts to a 53 percent loss over 200 years, or an average annual loss of 585,000 acres.

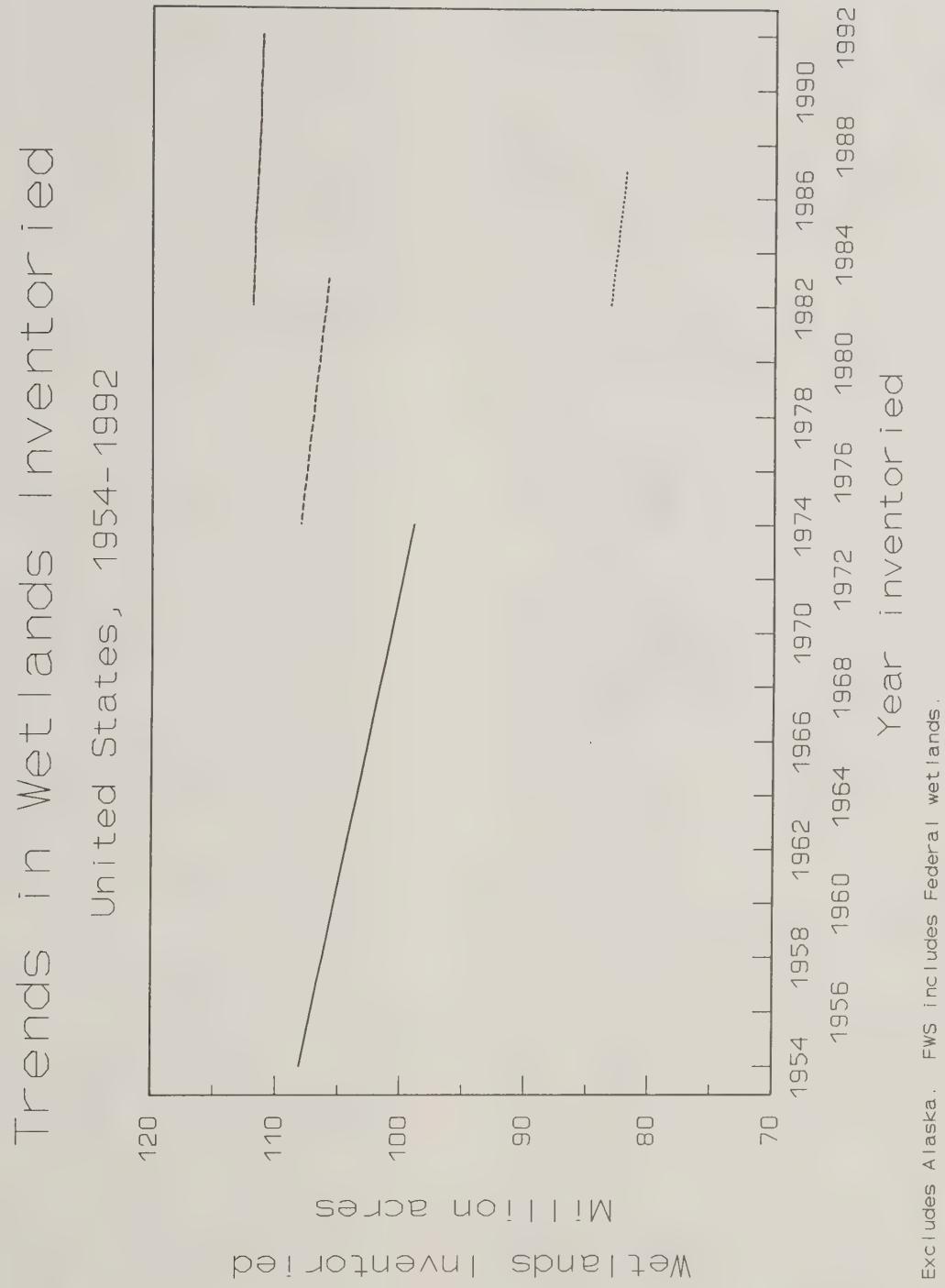
USDA conducted drainage inventories to identify lands suitable for drainage and assess the agricultural potential of remaining wetlands. In 1906, 79 million swampland acres (excluding Alaska) were thought to have farm potential, but two-thirds of this was not fit for cultivation unless drained and cleared. A more comprehensive inventory in 1919 showed

**Table 1. Wetland classifications in the 1992 National Resources Inventory**

| FSA Classification |   | Cowardin System |  |
|--------------------|---|-----------------|--|
| W                  | Wetlands                                  | 10              | Marine system                                |
| RPW                | Replacement wetland                       | 20              | Estuarine system/none or other vegetation    |
| RVW                | Restored wetland with violation           | 21              | Estuarine/emergent                           |
| GFW                | Good faith wetland                        | 22              | Estuarine/scrub-shrub                        |
| RSW                | Restored wetland                          | 23              | Estuarine/forested                           |
| CW                 | Converted wetland                         | 30              | Riverine system                              |
| CC                 | Commenced conversion                      | 31              | Riverine/nonpersistent emergent vegetation   |
| TP                 | Third party conversion                    | 40              | Lacustrine system                            |
| MW                 | Minimal-effect conversion                 | 41              | Lacustrine/nonpersistent emergent vegetation |
| CWNA               | Converted wetland/nonag use               | 50              | Palustrine system/none or other vegetation   |
| MIW                | Mitigated wetland                         | 51              | Palustrine/emergent                          |
| CWTE               | Converted wetland technical error         | 52              | Palustrine/scrub-shrub                       |
| PC                 | Prior converted wetland (before 12/23/85) | 53              | Palustrine/forested                          |
| FW                 | Farmed wetland                            |                 |  |
| AW                 | Artificial wetland                        |                 |  |
| NW                 | Not wetland                               |                 |  |

Source: 1992 National Resources Inventory, Supplemental Instructions for Collecting Wetlands Data (unpublished).

**Figure 1**



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91.5 million acres unfit for crops without drainage, but judged that only 75 million acres could ever be developed for agriculture. The American Society of Agricultural Engineers conducted a similar drainage survey in 1946-48 that identified 97 million acres of wet, swampy, or overflow lands. However, they judged only 20 million acres could be drained for farming at reasonable cost. A related 1948 SCS estimate showed 20.7 million acres physically feasible to drain and develop for agriculture.

The FWS, cooperating with State fish and game departments, conducted the inventory published as Circular 39 in 1954. For the first time, this inventory focused on managing wetlands, rather than eliminating them. It counted 74.4 million acres in the 20 Circular 39 wetland types. The National Wetland Status and Trends Analysis was conducted by the FWS in 1979 to not only identify current wetlands according to the Cowardin system, but estimate changes from the mid-1950's to the mid-1970's. Using aerial photographic techniques on 3,635 4-square mile units, this study estimated conversion of 13.8 million acres of public and private wetlands, offset by 6.2 million acres of wetland increase. On net, wetlands changed from 108.1 to 99.0 million acres in the lower 48 States. The most recent FWS estimates show a 2.6 million acre drop in wetlands in the lower 48 States, from 105.9 million acres in the mid-1970's to 103.3 million acres by the mid-1980's. The mid-1970's estimate was adjusted upward from the previous study because of better classification using improved color infrared aerial photography.

The 1958 Conservation Needs Inventory, conducted by USDA's Soil

Conservation Service, identified 73.5 million acres of land needing treatment for excess water, more than 80 percent of which was cropland. Some 172.5 million acres were judged to have drainage problems. Similar statistical spatial sampling methods were used in the 1975 Potential Cropland Survey to record 21.4 million acres of high and medium potential cropland suffering from wetness, but only 181,300 acres were identified as wetland types 3-20 in the Circular 39 classification, omitting the more extensive type 1 and 2 upland wetlands. The 1977 NRI identified 41.5 million acres of wetland types 3-20. The 1982 NRI inventoried all rural, nonfederal wetlands according to both the older Circular 39 and later Cowardin classifications. It found 78.4 million acres of wetlands. The 1987 NRI reclassified some of the sample points originally visited in 1982 to increase 1982 rural nonfederal wetlands to 83.2 million acres. A loss of 1.2 million acres was estimated to occur between 1982 and 1987, resulting in only 82 million wetland acres by the latter date.

The 1992 NRI reports a total of 156.6 million acres of wetlands and deepwater habitats on nonfederal lands (including the Hawaii and the Caribbean, but excluding Alaska) in 1992 and an analogous figure of 157.2 million acres in 1982. Unfortunately, this includes deepwater habitats, which were not coded in such a way as to be easily separated. Excluding water areas that are not wetlands as a proxy for deepwater habitats results in totals of 112.0 and 111.2 million acres of wetlands for 1982 and 1992, respectively. This figure excludes 394,500 acres of 1982 wetlands that changed to Federal ownership by 1992 and 6,200 acres of

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1982 Federal wetlands that changed to nonfederal ownership by 1992, but does include farmed wetlands not inventoried by FWS. SCS attributes the increase in wetland acreage with succeeding inventories to greater attention to wetlands, wetland delineation in response to FSA provisions, use of FWS National Wetland Inventory maps for field guidance, and use of State inventory teams versus District Conservationists for data collection.

### Trends in Agricultural Wetland Conversion

Average annual rates of wetland conversion have generally been falling since the first reliable scientific wetland inventories were taken in the mid-1950's (table 2). FWS estimated the net rate of wetland conversion between the mid-1950's and mid-1970's at 455,000 acres per year, mostly from upland (palustrine) wetlands. 87 percent of the 13.8 million acres of wetlands converted were to agricultural uses and 8 percent were to urban uses. A more recent study by FWS using similar methods records a decline in average wetland conversion to 288,900 acres per year for the mid-1970's to mid-1980's. Conversions to agricultural use accounted for a smaller 56 percent of average annual losses. However, much of the 41 percent converted to other uses was cleared and drained, possibly intended for agricultural use, but had not yet been put to an identifiable use at the end of the period. Urban uses were 3 percent of losses.

In the 1987 and 1992 NRI, some 1982 sample points were reclassified resulting in revisions to the original estimate of 78.4 million acres of wetlands made in the 1982 NRI. Based on changes at NRI sample

points between 1982 and 1987, the net rate of conversion dropped to 179,500 acres per year. Agriculture accounted for 24 percent of wetlands converted. A specific inventory of wetland NRI points done in 1991 provided an estimate of 107,750 acres of wetland lost annually between 1987 and 1991, of which agricultural conversion accounted for 27 percent (12). The 1992 NRI indicates an estimated 111.2 million acres of wetlands, down from a revised 1982 total of 112.0 million acres. This results in an average annual net loss of 80,300 acres per year between 1982 and 1992.

FWS-NWSTA and NRI data clearly seem to indicate a decline in both net and gross conversion rates, but estimating the magnitude of the decline across both data sets is risky because of differences in study methods. Most of the decline in average annual rates of wetland conversion from the mid-1950's to 1992 would appear to be due to reduced conversion for agricultural production. Urban development claims an acreage fluctuating between 14,100 and 88,600 acres per year which is a larger percentage of a decreased total conversion. "Other" uses, primarily deepwater and minor rural uses, claim 20,300 to 171,700 acres per year, a share of the total varying from 5 percent of high conversion totals in the 1950's and 1960's to 45 percent of reduced conversions in the 1980's.

Despite some doubt as to the size of the decline, the declining trend in overall wetland losses and the percentage of gross loss attributable to agricultural conversion is consistent with the hypothesis that a combination of economic conditions and policy changes have had some effect. Commodity prices and returns to

**Table 2. Extent and Changes in Wetlands, 1954 to 1992**

|                      | National Wetland Status and Trends 1/ |         |       |         |       | National Resources Inventories 2/ |         |      |         |         |
|----------------------|---------------------------------------|---------|-------|---------|-------|-----------------------------------|---------|------|---------|---------|
|                      | 1954                                  | 1954-74 | 1974  | 1974-83 | 1983  | 1982                              | 1982-87 | 1987 | 1987-91 | 1982-92 |
| Million acres        |                                       |         |       |         |       |                                   |         |      |         |         |
| Wetlands inventoried | 108.1                                 |         | 105.9 |         | 103.3 | 112.0                             |         | 82.0 |         | 111.2   |
| Original estimate 3/ |                                       | 99.0    |       |         | 78.4  |                                   |         |      |         |         |
| 1st revised estimate |                                       |         |       |         | 82.9  |                                   |         |      |         |         |
| Average annual       |                                       |         |       |         |       |                                   |         |      |         |         |
| Net change 4/        | 455.0                                 |         | 288.9 |         |       |                                   | 179.5   |      | na      | 80.3    |
| Conversion to:       |                                       |         |       |         |       |                                   |         |      |         |         |
| Agriculture          | 600.0                                 |         | 237.5 |         |       |                                   | 46.4    |      | 29.3    | 35.2    |
| Urban development    | 55.0                                  |         | 14.1  |         |       |                                   | 59.4    |      | 58.3    | 88.6    |
| Other                | 35.0                                  |         | 171.7 |         |       |                                   | 88.4    |      | 20.3    | 30.7    |
| Total                | 690.0                                 |         | 423.2 |         |       |                                   | 194.2   |      | 107.8   | 154.5   |
| Conversion to:       |                                       |         |       |         |       |                                   |         |      |         |         |
| Agriculture          | 87                                    |         | 56    |         |       |                                   | 24      |      | 27      | 23      |
| Urban development    | 8                                     |         | 3     |         |       |                                   | 31      |      | 54      | 57      |
| Other                | 5                                     |         | 41    |         |       |                                   | 45      |      | 19      | 20      |
| Total                | 100                                   |         | 100   |         |       |                                   | 100     |      | 100     | 100     |

Sources: 1/ U.S. Fish and Wildlife Service, National Wetland Status and Trends Analysis, mid-1950's to mid-1970's and mid-1970's to mid-1980's. Excludes Alaska and Hawaii. Excludes deepwater habitats.

2/ Soil Conservation Service, USDA, National Resources Inventories, 1982, 1987, 1992, and 1991 Wetlands Update. Includes only rural, nonfederal land. Excludes Alaska; includes Hawaii and Caribbean. Excludes estimated acreage of deepwater habitats. Wetland extent not estimated in 1991.

3/ The 1974 FWS wetland extent was increased because of better photo interpretation using color infrared photography not available earlier. The 1982 SCS inventory increased due to reclassification of 1982 sample points in the 1987 and 1992 inventories.

4/ Conversion of wetland to nonwetland uses, plus increases in wetlands due to restoration, abandonment, and flooding. Excludes change to or from Federal ownership.

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agricultural production have fallen since the 1950's, especially sharply in the 1980's. Policy changes brought about from Executive Order 11990 in 1978, passage of swamplibster provisions in the 1985 Food Security Act, elimination of tax advantages to wetland conversion in the 1986 Tax Reform Act, and more aggressive enforcement of Section 404 dredge and fill permits since 1989 have probably also reduced wetland conversion to agricultural use.

Economists have estimated changes in the profitability of wetland conversion over the last several decades that support this hypothesis. I reported on the results of a simulated 320-acre wetland conversion in North Carolina's Pocosin wetland region (3). In the base case, converted cropland would have had to have sold for \$3,105 per acre, almost double actual sales prices, to have made net incomes before and after the conversion equal. This indicates that at 1985 prices and costs, even without wetland policy reform, conversion profitability had declined from levels in the late 1970's that may have motivated these conversions. Loss of deficiency payments on all acres farmed reduced farm cash income by 36 percent and after-tax disposable income by 20 percent. The simulated cost of the Swamplibster sanction was \$903 per acre. The net present value of tax benefits lost because of the 1986 Tax Reform Act, including preferential treatment of capital gains on the sale of the converted land, was \$275 per acre.

Kramer and Shabman (7) simulated the mean net present value of returns per acre of bottomland hardwood conversion for three representative farm situations in Mississippi, Louisiana, and Arkansas.

Simulations reflecting conditions prior to wetland policy reforms in 1985 varied from an already marginal -\$1.50 per acre in Louisiana to a profitable \$449 per acre return in Arkansas. Under simulated 1987 prices and costs, but without wetland policy reforms in place, returns declined to -\$43 and \$92 in Louisiana and Mississippi and increased to \$632 in Arkansas. Conversion profitability was always questionable in the Louisiana example, and for two of the three States, changes in crop prices and production costs by 1987 substantially reduced incentives for conversion, even in the absence of wetland policy reforms.

Simulations for 1987, including the Swamplibster reform of denying farm program benefits and the income tax reform of denying drainage deductions (but not preferential capital gains treatment), showed returns of -\$127 and -\$236 per acre for the Mississippi and Louisiana examples and reduced Arkansas returns to \$271 per acre. Thus, the Swamplibster reform reduced conversion profitability by \$123-266 per acre, tax reform cost \$79-97 per acre, and the total reduction in drainage incentives due to reform was \$193-361 per acre. These estimates do not include the loss of farm program benefits on acreage in the farm not drained, estimated at \$114-264 per undrained acre. Not only were the average simulated returns lower because of policy reforms and declining market conditions, but the riskiness of wetland conversion investments, measured by the standard deviation of returns around the mean values, also increased.

McColloch, Wissman, and Richardson (8) simulated wetland conversion

economics for six representative Prairie Pothole farms in Montana, the Dakotas, and Minnesota between 1975 and 1984. In all cases, drainage increased the net present value of returns for the simulated farms by 25 to 303 percent over baseline simulations without drainage and increased acreage cropped. At prices prevailing in the decade before 1984, Swampbuster's loss of price and income support payments alone would not have been enough to discourage drainage in the pothole region. While returns dropped from 3.7 to 36.4 percent (\$300-706 per acre drained), all returns to drainage without farm program payments were larger than baseline returns. Loss of income tax deductions for drainage had little or no effect on the simulated farms in these cases because immediate deduction was actually less profitable than capitalizing drainage costs. The authors conclude that policy reform, had it been enacted in the period 1975-84, would have had mixed results on farms in Prairie Pothole region. It would have been more effective in keeping larger farms from draining than smaller farms. Moderate and small farms would still have found it more profitable to drain than not. Swanson (13) estimated potential profits from drainage enterprises in varying situations on eight representative farms in the Rainwater Basin of Nebraska between 1970 and 1985 and projected to 1995. He concluded that drainage of the smaller and shallower wetlands for intensified cropping was profitable, but that drainage of deeper, wetter basins became increasingly unprofitable after the mid-1970's. Swanson discussed the Swampbuster and tax reform provisions then under consideration, but did not estimate changes in returns with and without these policy reforms.

### Shifts Between Wetland and Nonwetland Uses

Analysis of the complete matrix of land use changes involving wetlands is now possible because the NRI is repeatedly collected at the same sample points. This kind of analysis is illustrated here using 1992 NRI data for the 1982-92 period. Unlike some land use classification schemes, "wetland" is reported as a condition in the NRI, not a separate land use/cover. This method of reporting means that the initial wetland base in 1982 can suffer three possible fates:

- Remain as wetland in the same use or cover;
- Change between wetland land uses or covers;
- Be converted out of wetland condition into various nonwetland land uses or covers;

In addition, the 1982 wetland base can be augmented from nonwetland changed to wetland condition in various land uses or covers. Because the NRI does not inventory Federal land, changes of wetlands to and from Federal ownership must be allowed for in the transition matrix as well. The various fates require expanding the familiar land use change matrix into the three-part matrix of table 3.

From table 3, of 112 million acres of wetlands in 1982 (excluding 394.5 thousand acres entering Federal ownership by 1992), 1.5 million acres were converted to nonwetland uses and 741.5 thousand acres of nonwetlands were converted to wetlands, leaving 111.2 million acres of wetlands in 1992. In the upper left quadrant of the table, while some changes in use between 1982 and 1992 occurred within the wetlands inventoried in 1982,

Table 3. Wetland Land Use/Cover Change Matrix, 1982-92

|                            |          | 1992 Wetland Use (thousand acres)          |         |          |          |             |           | 1992 Nonwetland Use (thousand acres) |                 |          |          |         |       |        |             |           |          |            |         |
|----------------------------|----------|--|---------|----------|----------|-------------|-----------|--------------------------------------|-----------------|----------|----------|---------|-------|--------|-------------|-----------|----------|------------|---------|
|                            |          | Cropland                                   | Pasture | Range    | Forest   | Other rural | Developed | Water < 2 acres                      | Water > 2 acres | Subtotal | Cropland | Pasture | Range | Forest | Other rural | Developed | Water 1/ | 1982 total | Federal |
| <b>1982 Wetland use</b>    |          | Between wetland uses between 1982 and 1992 |         |          |          |             |           |                                      |                 |          |          |         |       |        |             |           |          |            |         |
| Cropland                   | 9,451.0  | 727.4                                      | 60.9    | 216.5    | 701.9    | 17.6        | 6.0       | 24.8                                 | 11,206.1        | 31.7     | .4       | 0.0     | 0.0   | 0.0    | 63.6        | 12.5      | 11,314.3 | 2.8        |         |
| Pasture                    | 540.5    | 6,872.0                                    | 66.4    | 671.0    | 284.2    | 32.7        | 15.5      | 12.1                                 | 8,494.4         | 25.0     | 1.5      | 0.0     | 0.0   | 2.2    | 108.6       | 27.3      | 8,659.0  | 0.8        |         |
| Range                      | 291.5    | 155.6                                      | 7,579.3 | 84.1     | 110.0    | 17.1        | 8.9       | 15.7                                 | 8,262.2         | 7.4      | 2.0      | 12.6    | 0.7   | 2.8    | 46.6        | 13.8      | 8,338.1  | 35.8       |         |
| Forest                     | 156.3    | 174.5                                      | 19.4    | 59,778.0 | 148.3    | 79.6        | 21.2      | 45.9                                 | 60,423.2        | 95.1     | 6.0      | 0.0     | 4.9   | 7.3    | 629.0       | 64.8      | 61,230.3 | 309.1      |         |
| Other rural                | 97.8     | 39.0                                       | 9.2     | 269.1    | 17,345.0 | 8.0         | 2.2       | 11.4                                 | 17,781.7        | 22.5     | 0.0      | 4.9     | 0.0   | 24.0   | 28.0        | 66.9      | 17,928.0 | 44.9       |         |
| Developed                  | 0.0      | 0.0  | 0.0     | 0.0      | 1,340.5  | 0.0         | 0.0       | 0.0                                  | 1,340.5         | 0.0      | 0.0      | 0.0     | 0.0   | 0.0    | 0.0         | 9.7       | 0.0      | 1,350.2    | 0.0     |
| Water < 2 acres            | 2.2      | 4.1  | 4.3     | 2.7      | 11.6     | 0.0         | 1,074.9   | 31.8                                 | 1,131.6         | 23.1     | 22.0     | 13.3    | 25.1  | 4.3    | .3          | 1.5       | 1,221.2  | 0.0        |         |
| Water > 2 acres            | 6.2      | 6.3  | 6.8     | 6.2      | 7.2      | .5          | 11.3      | 1,773.7                              | 1,818.2         | 35.3     | 23.2     | 25.5    | 33.4  | 3.2    | .1          | 12.6      | 1,951.2  | 1.1        |         |
| <b>1982 Nonwetland use</b> |          | Into wetland uses by 1992                  |         |          |          |             |           |                                      |                 |          |          |         |       |        |             |           |          |            |         |
| Cropland                   | 1.8      | 2.5  | 0.0     | 52.0     | 72.2     | .6          | 58.0      | 86.3                                 | 273.4           |          |          |         |       |        |             |           |          |            |         |
| Pasture                    | 0.0      | 2.6  | 0.0     | 10.7     | 14.8     | 0.0         | 56.8      | 38.8                                 | 123.7           |          |          |         |       |        |             |           |          |            |         |
| Range                      | 0.0      | 0.0  | 8.7     | 0.0      | 26.7     | 0.0         | 29.2      | 44.5                                 | 109.1           |          |          |         |       |        |             |           |          |            |         |
| Forest                     | 0.0      | 0.0  | 0.0     | 9.3      | 14.7     | 0.0         | 50.6      | 68.5                                 | 143.1           |          |          |         |       |        |             |           |          |            |         |
| Other rural                | 1.9      | 0.0  | 0.0     | 4.9      | 7.9      | 0.0         | 8.1       | 2.8                                  | 25.6            |          |          |         |       |        |             |           |          |            |         |
| Developed                  | 0.0      | 0.0  | 0.0     | 0.0      | 14.1     | 0.0         | .5        | 14.6                                 |                 |          |          |         |       |        |             |           |          |            |         |
| Water 1/                   | 1.4      | 0.0  | 8.6     | 6.1      | 17.4     | 0.0         | 5.9       | 12.6                                 | 52.0            |          |          |         |       |        |             |           |          |            |         |
| Total 1992                 | 10,550.6 | 7,984.0                                    | 7,763.6 | 61,110.6 | 18,761.9 | 1,510.7     | 1,348.6   | 2,169.4                              | 741.5           |          |          |         |       |        |             |           |          |            |         |
| Federal                    | 0.0      | 2.0  | 0.0     | 2.7      | 1.5      | 0.0         | 0.0       | 0.0                                  | 6.2             |          |          |         |       |        |             |           |          |            |         |
|                            |          |  |         |          |          |             |           |                                      |                 |          |          |         |       |        |             |           |          |            |         |
|                            |          |  |         |          |          |             |           |                                      |                 |          |          |         |       |        |             |           |          |            |         |
|                            |          |  |         |          |          |             |           |                                      |                 |          |          |         |       |        |             |           |          |            |         |
|                            |          |  |         |          |          |             |           |                                      |                 |          |          |         |       |        |             |           |          |            |         |
|                            |          |  |         |          |          |             |           |                                      |                 |          |          |         |       |        |             |           |          |            |         |
|                            |          |  |         |          |          |             |           |                                      |                 |          |          |         |       |        |             |           |          |            |         |
|                            |          |  |         |          |          |             |           |                                      |                 |          |          |         |       |        |             |           |          |            |         |
|                            |          |  |         |          |          |             |           |                                      |                 |          |          |         |       |        |             |           |          |            |         |
|                            |          |  |         |          |          |             |           |                                      |                 |          |          |         |       |        |             |           |          |            |         |
|                            |          |  |         |          |          |             |           |                                      |                 |          |          |         |       |        |             |           |          |            |         |
|                            |          |  |         |          |          |             |           |                                      |                 |          |          |         |       |        |             |           |          |            |         |
|                            |          |  |         |          |          |             |           |                                      |                 |          |          |         |       |        |             |           |          |            |         |
|                            |          |  |         |          |          |             |           |                                      |                 |          |          |         |       |        |             |           |          |            |         |
|                            |          |  |         |          |          |             |           |                                      |                 |          |          |         |       |        |             |           |          |            |         |
|                            |          |  |         |          |          |             |           |                                      |                 |          |          |         |       |        |             |           |          |            |         |
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|                            |          |  |         |          |          |             |           |                                      |                 |          |          |         |       |        |             |           |          |            |         |
|                            |          |  |         |          |          |             |           |                                      |                 |          |          |         |       |        |             |           |          |            |         |
|                            |          |  |         |          |          |             |           |                                      |                 |          |          |         |       |        |             |           |          |            |         |
|                            |          |  |         |          |          |             |           |                                      |                 |          |          |         |       |        |             |           |          |            |         |
|                            |          |  |         |          |          |             |           |                                      |                 |          |          |         |       |        |             |           |          |            |         |
|                            |          |  |         |          |          |             |           |                                      |                 |          |          |         |       |        |             |           |          |            |         |
|                            |          |  |         |          |          |             |           |                                      |                 |          |          |         |       |        |             |           |          |            |         |
|                            |          |  |         |          |          |             |           |                                      |                 |          |          |         |       |        |             |           |          |            |         |
|                            |          |  |         |          |          |             |           |                                      |                 |          |          |         |       |        |             |           |          |            |         |
|                            |          |  |         |          |          |             |           |                                      |                 |          |          |         |       |        |             |           |          |            |         |
|                            |          |  |         |          |          |             |           |                                      |                 |          |          |         |       |        |             |           |          |            |         |
|                            |          |  |         |          |          |             |           |                                      |                 |          |          |         |       |        |             |           |          |            |         |
|                            |          |  |         |          |          |             |           |                                      |                 |          |          |         |       |        |             |           |          |            |         |
|                            |          |  |         |          |          |             |           |                                      |                 |          |          |         |       |        |             |           |          |            |         |
|                            |          |  |         |          |          |             |           |                                      |                 |          |          |         |       |        |             |           |          |            |         |
|                            |          |  |         |          |          |             |           |                                      |                 |          |          |         |       |        |             |           |          |            |         |
|                            |          |  |         |          |          |             |           |                                      |                 |          |          |         |       |        |             |           |          |            |         |
|                            |          |  |         |          |          |             |           |                                      |                 |          |          |         |       |        |             |           |          |            |         |
|                            |          |  |         |          |          |             |           |                                      |                 |          |          |         |       |        |             |           |          |            |         |
|                            |          |  |         |          |          |             |           |                                      |                 |          |          |         |       |        |             |           |          |            |         |
|                            |          |  |         |          |          |             |           |                                      |                 |          |          |         |       |        |             |           |          |            |         |
|                            |          |  |         |          |          |             |           |                                      |                 |          |          |         |       |        |             |           |          |            |         |
|                            |          |  |         |          |          |             |           |                                      |                 |          |          |         |       |        |             |           |          |            |         |
|                            |          |  |         |          |          |             |           |                                      |                 |          |          |         |       |        |             |           |          |            |         |
|                            |          |  |         |          |          |             |           |                                      |                 |          |          |         |       |        |             |           |          |            |         |
|                            |          |  |         |          |          |             |           |                                      |                 |          |          |         |       |        |             |           |          |            |         |
|                            |          |  |         |          |          |             |           |                                      |                 |          |          |         |       |        |             |           |          |            |         |
|                            |          |  |         |          |          |             |           |                                      |                 |          |          |         |       |        |             |           |          |            |         |
|                            |          |  |         |          |          |             |           |                                      |                 |          |          |         |       |        |             |           |          |            |         |
|                            |          |  |         |          |          |             |           |                                      |                 |          |          |         |       |        |             |           |          |            |         |
|                            |          |  |         |          |          |             |           |                                      |                 |          |          |         |       |        |             |           |          |            |         |
|                            |          |  |         |          |          |             |           |                                      |                 |          |          |         |       |        |             |           |          |            |         |
|                            |          |  |         |          |          |             |           |                                      |                 |          |          |         |       |        |             |           |          |            |         |
|                            |          |  |         |          |          |             |           |                                      |                 |          |          |         |       |        |             |           |          |            |         |
|                            |          |  |         |          |          |             |           |                                      |                 |          |          |         |       |        |             |           |          |            |         |
|                            |          |  |         |          |          |             |           |                                      |                 |          |          |         |       |        |             |           |          |            |         |
|                            |          |  |         |          |          |             |           |                                      |                 |          |          |         |       |        |             |           |          |            |         |
|                            |          |  |         |          |          |             |           |                                      |                 |          |          |         |       |        |             |           |          |            |         |
|                            |          |  |         |          |          |             |           |                                      |                 |          |          |         |       |        |             |           |          |            |         |

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81 to 100 percent remained in their original land use/cover, shown as the diagonal elements. The largest change in use occurred with wetland pasture, with 1.6 million acres changing to other uses ( $540.5 + 66.4 + 671.0 + 284.2 + 32.7 + 15.5 + 12.1$ ) and 1.1 million acres moving from other uses to wetland pasture ( $727.4 + 155.6 + 174.5 + 39 + 4.1 + 6.3$ ).

In the upper right quadrant, 199.4 thousand acres of 1982 wetlands had become nonwetland open water by 1992, 885.9 thousand acres had been converted to developed uses, and 240.1 thousand acres had been drained and converted to cropland. The 394.5 thousand acres of new federal land in the last column are not counted as conversion because they probably only changed ownership and were not lost as wetlands, merely lost to the inventory. In the lower left quadrant, 53 thousand acres of nonwetland open water, 123.7 thousand acres of pasture, and 273.4 thousand acres of cropland had changed to wetland by 1992.

#### Wetlands Subject to Swampbuster

Up to now, there has been no reliable estimate of the total farmland acreage subject to swampbuster. Previously available data indicated some realistic limits. According to the 1982 and 1987 NRIs there were between 78.4 and 83.2 million acres of rural nonfederal wetlands classified according to the Cowardin system in 1982. All of this wetland is subject to swampbuster provisions, if the landowner participates in farm programs. However, only 6-7 percent (4.7-5.7 million acres) was rated by SCS technicians as having high or medium potential for conversion to cropland. Another 4.4-5.0 million acres of wetlands

were used for crop production, but still classified as wetlands and presumably subject to swampbuster provisions.

In addition to land inventoried as wetland, 101.4 million acres of land inventoried in 1987 had hydric soils. Land with hydric soils may be subject to swampbuster provisions if it is still sufficiently wet to support hydrophytic vegetation. Of this land, 57.9 million acres of nonwetland cropland on hydric soils can be identified. Some 36.5 million acres of this land are rated as poorly drained. More than half of this land (30 million acres) had no drainage. Half of that (17.9 million acres) needed drainage or other conservation practices for improved crop production. The remaining land was drained to some degree, but 4.5 million acres was not adequately drained for best crop production.

Technically, as much as 179.8-184.6 million acres, including all wetlands and any land on hydric soils that has not been completely drained, is subject to swampbuster provisions. Realistically, only inventoried wetlands and poorly drained hydric cropland and pasture is likely to be affected, amounting to some 124.9-129.7 million acres. The amount of land with some likelihood for conversion activity is even smaller, including some 22.6-23.6 million acres of wetlands with high and medium conversion potential and hydric cropland needing drainage for improved crop production. Further adjustment is needed because only 85 percent of rural nonfederal wetlands are privately owned. The proportion of privately owned wetlands actually owned by farmers and participating in farm programs is not known.

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By including wetland exemption categories developed in support of 1985 Food Security Act wetland determinations in the 1992 NRI, SCS has made it possible to estimate what kinds of land uses are subject to swambuster and the overlap between scientifically defined wetlands and swambuster jurisdictional wetlands.

Some 92.8 million acres of land are estimated to be wetlands subject to the swambuster provision, 83 percent of the 111.2 million acres of wetlands on nonfederal land (table 4). The remaining 18.4 million acres (111.2-92.8) of wetlands not covered in FSA designations is probably not on farms. Another 52.6 million acres are prior converted wetlands. Cropland makes up 5.8 million acres of FSA wetlands, about evenly split between natural and farmed wetlands. Another 6.8 million acres of FSA wetlands are in pasture cover and 7.1 million acres are range. The largest cover or use of FSA wetlands is forest, at 56 million acres. Most of the prior converted wetlands are in cropland use or cover, encompassing 48.4 million acres or 92 percent.

The steady expansion of wetlands inventoried in the NRI from 1982 to 1992 probably reflects greater scrutiny of possible wetland sites at least in part due to implementing the swambuster provisions. The almost 34 million acre difference between the original 1982 wetlands and the revisions made for the 1992 NRI includes 6.9 million acres of cropped wetlands, 4.1 million acres of wetland pasture and range, and 18.6 million acres of wet forest. However, only 14.4 million acres more FSA wetlands were inventoried in 1992 than total wetlands in 1982, including 1.4 million more wet cropland acres, 1 million

acres more wet pasture and range acres, and 13.4 million acres of wet forest.

More than 66.4 million acres of FSA wetlands (72 percent) are in the palustrine or upland wetland system of the Cowardin classification and most of these are forested wetlands (table 5). On the other hand, 47.5 million acres of prior converted FSA wetlands are not wetlands in the Cowardin classification, but 5.1 million acres are Cowardin wetlands, mostly in the palustrine system. In general, there is good agreement between the FSA and Cowardin classifications, as recorded by SCS in the NRI. Of 92.8 million acres of FSA wetlands, all but 124,400 acres are also Cowardin wetlands. However, another 5.1 million acres of FSA prior converted wetlands are also wetlands in the Cowardin system, with most of these in the palustrine and palustrine emergent systems. In addition, 8.4 million acres of Cowardin wetlands are classified as not wetlands for FSA, with over half of these in the palustrine forested system.

One of the outstanding characteristics of the National Resources Inventory databases is the fact that current information on land use and cultivation is linked with more enduring soil interpretive material from the SOILS 5 databases. This is particularly important in the area of wetland policy analysis, because one of the defining criteria for wetlands is presence of hydric soils. Hydric soils are soils that in their undrained condition are saturated, flooded, or ponded long enough during the growing season to develop anaerobic conditions that favor the growth of hydrophytic (water-loving) plants. Soil retains characteristics of formation under anaerobic conditions typical of wetlands long after wetland vegetation has been removed and the

**Table 4. Food Security Act wetlands by broad use, 1992**

| Broad use<br>(thousand<br>acres) | FSA wetland codes      |                                |                               |                            |          |  |                         | Total       |
|----------------------------------|------------------------|--------------------------------|-------------------------------|----------------------------|----------|--|-------------------------|-------------|
|                                  | FSA<br>wetlands<br>(W) | Artificial<br>wetlands<br>(AW) | Converted<br>wetlands<br>(CW) | Farmed<br>wetlands<br>(FW) | Subtotal | Prior<br>converted<br>wetlands<br>(PC) | Not<br>wetlands<br>(NW) |             |
| Cropland                         | 2,990.7                | 203.6                          | 128.4                         | 2,475.8                    | 5,798.5  | 48,422.0                               | 328,097.0               | 382,317.0   |
| Pasture                          | 5,162.3                | 247.7                          | 83.0                          | 1,288.1                    | 6,781.1  | 2,364.2                                | 116,781.0               | 125,927.0   |
| Range                            | 6,802.0                | 275.4                          | 4.0                           | 0.0                        | 7,081.4  | 108.7                                  | 391,758.0               | 398,949.0   |
| Forest                           | 55,973.0               | 11.5                           | 30.6                          | 0.0                        | 56,015.1 | 305.8                                  | 338,637.0               | 394,958.0   |
| Other<br>rural                   | 16,818.0               | 139.6                          | 40.4                          | 98.0                       | 17,096.0 | 1,446.1                                | 70,082.0                | 88,624.0    |
| Total                            | 87,745.7               | 877.8                          | 286.4                         | 3,861.9                    | 92,772.1 | 52,646.7                               | 1,245,355.0             | 1,390,774.0 |

Source: 1992 National Resources Inventory

Total excludes 549,237.5 thousand acres for which the FSA determination was missing.

wetland has been drained. Thus, presence of hydric soil types is an indication of previous wetland condition. Hydric soils are also the most likely candidates for restoration to wetland, particularly if they have not been fully drained.

### Wetland Restoration

In 1988, when I first began to analyze the potential for a wetland reserve program, I had to merge a computer tape file of the hydric soil list to the 1982 NRI file using variables such as SOILS 5 number, land capability class and subclass, and other characteristics (SCS, 1985; Heimlich, et al., 1989). Hydric soils were added to the SOILS 5 database with the 1987 NRI. With these and other SOILS 5 data, it is possible to identify the pool of cropland converted from wetlands that could be enrolled in a reserve, estimate wetland restoration costs, and calculate the opportunity cost of enrolling the cropland in the reserve (5).

Of nearly 163 million acres of land with hydric soils inventoried in the 1982 NRI, only 61.5 million acres (78 percent) of wetlands are associated with hydric soils, probably due to incomplete soil surveys or lack of specific soil information in some land uses, particularly forestland (table 6). More than 101 million acres of hydric land are former wetlands that have lost wetland hydrology, either directly through drainage or indirectly as a result of other changes in hydrology. Crop and forest uses make up 84 percent of former wetlands on hydric soils, indicating that most of the conversion has been for an economic purpose. These lands form a pool of potentially restorable wetlands for programs such as the Wetland Reserve Program. The 1992 NRI can be used to conduct an analysis of current and former wetlands on hydric soils similar to the one presented here.

**Table 5. Food Security Act wetlands by Cowardin classification, 1992**

| Cowardin system                   | FSA wetland code |                          |                         |                      |          |                               |                   | Total       |
|-----------------------------------|------------------|--------------------------|-------------------------|----------------------|----------|-------------------------------|-------------------|-------------|
|                                   | FSA wetlands (W) | Artificial wetlands (AW) | Converted wetlands (CW) | Farmed wetlands (FW) | Subtotal | Prior converted wetlands (PC) | Not wetlands (NW) |             |
| Not wetlands                      | 0.0              | 0.0                      | 124.4                   | 0.0                  | 124.4    | 47,524.0                      | 1,236,948.0       | 1,284,596.0 |
| Marine                            | 11.8             | 0.0                      | 0.0                     | 0.0                  | 11.8     | 0.0                           | 19.9              | 31.7        |
| Estuarine                         | 170.6            | 0.0                      | 0.0                     | 0.0                  | 170.6    | 0.0                           | 58.1              | 228.7       |
| Estuarine emergent                | 3,884.4          | 0.0                      | 0.0                     | 2.4                  | 3,886.8  | 0.0                           | 527.0             | 4,413.8     |
| Estuarine scrub/shrub             | 93.2             | 0.0                      | 0.0                     | 0.0                  | 93.2     | 0.0                           | 5.0               | 98.2        |
| Estuarine forested                | 209.3            | 0.0                      | 0.0                     | 0.0                  | 209.3    | 0.0                           | 25.0              | 234.3       |
| Riverine                          | 443.2            | 11.5                     | 0.0                     | 1.1                  | 455.8    | 24.4                          | 192.9             | 673.1       |
| Riverine emergent-nonpersistent   | 214.4            | 1.7                      | 0.0                     | 7.9                  | 224.0    | 0.0                           | 51.6              | 275.6       |
| Lacustrine                        | 347.0            | 3.7                      | 0.0                     | 0.0                  | 350.7    | 0.0                           | 22.5              | 373.2       |
| Lacustrine emergent-nonpersistent | 40.1             | 6.3                      | 0.0                     | 0.0                  | 46.4     | 0.0                           | 0.0               | 46.4        |
| Palustrine                        | 3,540.3          | 169.9                    | 85.6                    | 1,754.1              | 5,549.9  | 2,259.3                       | 1,134.7           | 8,943.9     |
| Palustrine emergent               | 18,033.0         | 596.2                    | 60.8                    | 2,079.0              | 20,769.0 | 2,712.8                       | 992.4             | 24,474.0    |
| Palustrine scrub/shrub            | 5,934.4          | 69.3                     | 6.9                     | 10.9                 | 6,021.5  | 23.0                          | 575.4             | 6,619.9     |
| Palustrine forested               | 54,824.0         | 19.2                     | 8.7                     | 6.5                  | 54,858.4 | 103.1                         | 4,803.0           | 59,764.0    |
| Total                             | 87,745.7         | 877.8                    | 286.4                   | 3,861.9              | 92,771.8 | 52,646.7                      | 1,245,355.0       | 1,390,774.0 |

Source: 1992 National Resources Inventory

Total excludes 549,237.5 thousand acres for which the FSA determination was missing.

**Table 6. Land on Hydric Soils, by Land Cover/Use, 1982**

| Land Use/Cover       | Wetlands | Former wetlands | Total hydric soils |
|----------------------|----------|-----------------|--------------------|
| Thousand acres       |          |                 |                    |
| Cropland             | 2,841.5  | 57,899.0        | 60,740.5           |
| Pasture              | 3,407.1  | 10,014.0        | 13,421.1           |
| Rangeland            | 4,741.0  | 4,396.2         | 9,137.2            |
| Forest land          | 34,515.9 | 27,541.2        | 62,057.1           |
| Other land in farms  | 228.0    | 761.5           | 989.5              |
| Barren land          | 444.9    | 138.0           | 582.9              |
| Other lands          | 15,346.6 | 559.0           | 15,905.6           |
| Rural transportation | 5.2      | 111.0           | 116.2              |
| Total                | 61,530.2 | 101,419.9       | 162,950.1          |

Sources: 1982 National Resources Inventory and Soil Interpretations Records (Soils 5).

### Conclusions

Wetlands data collected in the National Resources Inventories has greatly improved since 1977. The 1992 NRI offers the most comprehensive data on wetland characteristics and extent ever developed by USDA. Nevertheless, there remains room for improvement. It is in the spirit of constructive criticism that the following suggestions and observations are offered.

First and most obvious is the disturbing problem of large changes in wetland acreage between inventories. The 1987 NRI estimate of 1982 wetlands jumped 4.8 million acres from 78.4 to 83.2 million acres. The adjustment in 1992 is even larger, jumping 33.6 million acres from 78.4 to 112 million acres, even after the adjustment for deepwater habitats

discussed below. A careful explanation should be presented to the public for adjustments of this magnitude to maintain credibility in the NRI process. USDA officials attribute this adjustment to widespread use of FWS National Wetland Inventory maps, use of better trained inventory teams in place of district officials, and greater sensitivity to the importance of wetlands policy. Wetland determinations for swambuster purposes probably also increased awareness of wetlands in the landscape. The problem of adjustments between inventories is one which FWS shares with their Status and Trends analyses. USDA and FWS should work together to insure that their inventories are as consistent as possible, recognizing some degree of irreconcilable

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differences due to different survey methods.

As discussed above, wetlands and deepwater habitats cannot be readily distinguished in the 1992 NRI data. This should be corrected in subsequent inventories. More immediately, a consistent method for segregating wetland and deepwater habitat records on the basis of land cover and other characteristics should be developed and applied to the data to recode existing observations.

Looking ahead, there are some additional wetland data elements that could be usefully collected in succeeding NRI's. First, some measure of the quality of the wetland could be developed and collected to get a better feel for the condition of existing wetland resources as well as their extent. This might be combined with an assessment of enhancement potential for existing and restoration potential for prior converted wetlands. Enhancement potential would assess the feasibility and practicality of improving existing wetlands condition to achieve full function and wetland values. Restoration potential would assess the similar, but more demanding task of changing cover and hydrologic characteristics that have been completely altered from original wetland status. This information would be extremely valuable for what is expected to be a growing movement toward restoring aquatic ecosystems in such programs as the Wetland Reserve Program, species recovery plans under an ecosystems-based Endangered Species Act, and improving nonpoint source water quality problems in watershed-based programs under a reauthorized Clean Water Act and Coastal Zone Act amendments (9).

Related data items could describe the location of inventoried wetlands within floodplains of varying expected duration and the potential for existing or restorable wetlands to contribute to reduction of flood damages in those floodplains. For example, is an inventoried wetland in the 100-year or 10-year floodplain? What is its position in the landscape relative to upstream or downstream impoundments or other flood control structures? To population concentrations? This information could contribute to floodplain management strategies and planning at the national and regional level that have been given new impetus following major Midwest floods in 1993 (6).

Finally, economic analyses of the potential for changing land use on wetlands and former wetlands would be enhanced by providing additional data on the drainage status of inventoried wetlands and prior converted wetlands and by ensuring that accurate soil interpretive information in SOILS 5 reflects differences between drained and undrained phases of wetland soils. Currently, drainage practices are recorded as one of a broad range of conservation practices that might be installed at a point. A maximum of three practices may be recorded for a point. If other, more visible practices are present as well as drainage, it may be omitted. Specific data fields for drainage used only for sample points that are wetlands or prior converted wetlands could provide more complete information. SOILS 5 soil interpretive information on expected crop yields supposedly differentiates between drained and undrained phases of soils, but records with drainage phase differences are limited. Providing better information on differences

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in expected yields would improve economic analyses of the opportunity costs of agricultural production that would be increased by wetland conversion or foregone through restoration.

These few improvements would make an already tremendously useful data set even more useful. They would follow in what has now become a long tradition of improving data collection for analysis of wetlands and wetland policy associated with agriculture in the National Resources Inventories.

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# Evaluating the CRP Using the 1992 National Resources Inventory

By Michael R. Dicks and  
John E. Coombs\*

## Introduction

What should be done with the Conservation Reserve Program (CRP)? This is the topic of considerable discussion within the agriculture, environmental and conservation, and legislative communities. Some agricultural producers support continuation of the CRP contracts on the basis of improved economic returns associated with either large annual rental payments or the commodity price increases resulting from the CRP's cropland base retirement. Other producers argue that the CRP has made land resources tight, increasing land values and cash rental rates and has increased pest problems. Environmental and conservation groups have extolled the programs positive attributes such as wildlife enhancement, soil savings, reduced input use, and supply control cost savings.

The most frequently requested information about the CRP, from all groups, pertains to the level of benefits and costs associated with the program. Several measures for soil savings, water quality benefits, wildlife enhancement, productivity gains, and supply control cost savings have been provided through various studies. However, most of these are national estimates made during the early years of the CRP (1986-88), and the benefits were determined by comparing land use at the time of enrollment to land use while in the CRP. Because land use is continually changing, the affect of the CRP (benefits) may be changing over time as well. The measure of benefits and costs of the CRP will be critical in the debate on the program's fate. Therefore, every effort to measure, as precisely as possible, the benefits of the CRP must be pursued.

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The difference between the environmental amenities that can be expected to occur in the absence of the CRP and those expected with the CRP and/or other land use options (policy induced or otherwise) provides the best basis for debating the fate of the CRP. The debate on the fate of CRP should remain fixed to arriving at a solution which provides a net gain to society. This paper addresses whether the use of the 1992 NRI can provide assistance in this determination.

More specifically the NRI is used to review the soil erosion problem, determine a "baseline" for the changing natural resource base, and assist in the measure of various environmental amenities.

## Background

The National Resource Inventory (NRI) indicates that in the United States, about 4.9 billion tons of soil are removed annually by soil erosion, approximately two-thirds by water and one-third by wind, down from nearly 6.1 billion tons of soil that eroded in 1982. Total erosion was reduced by nearly 1 billion tons per acre annually on cropland between 1982 (3.1 billion tons) and 1992 (2.1 billion tons). The majority of the soil savings (71 percent) occurred as a result of the decline in cultivate acreage between the two periods. A net loss of 41 million acres of cultivated cropland occurred between 1982 and 1992. However, about 71 million acres that were cultivated in 1982 were not cultivated in 1992 (Table 1). An average

annual water and wind erosion loss from croplands of 8.3 tons per acre occurred in 1982 compared to the annual average loss of 6.3 tons per acre in 1992. An annual average soil savings of approximately 1.6 ton per acre occurred on the cropland that was continuously cultivated between 1982 and 1992. The 1992 NRI also showed that in 1982 about 45 percent of United States cropland has an annual erosion loss from water and wind erosion in excess of 5 tons per acre per year, the maximum level that can occur on most soils before a net soil loss begins compared to 48 percent in 1992<sup>1</sup>.

Soil erosion varies from field to field and is dependent on the soil's physical properties and the farm operator's management practices. The loss of soil through erosion threatens the productivity of the land and the quality of the environment. The Conservation Reserve Program (CRP) was legislated within the Conservation Title of the Food Security Act of 1985 (FSA85) to address public concerns about on-site productivity damages and the environmental or off-site costs associated with soil erosion. However, several secondary goals were also attached to the CRP including reduced surplus commodity production, increased farm income and increased wildlife benefits. Today there are over 36 million acres of cropland enrolled in the CRP. Nearly two-thirds of this cropland has a crop base history. The majority of the land has been enrolled in the Great Plains<sup>2</sup> and the majority of the cropland base is wheat base.

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<sup>1</sup> Roughly 75 percent of the nations soils regenerate at about 5 tons per acre annually.

<sup>2</sup> The Great Plains includes North and South Dakota, Nebraska, Kansas, Oklahoma, Texas, New Mexico, Colorado, Wyoming, and Montana.

**Table 1. Cultivated Acreage Distribution by EI Class for 1982 and 1992.**

|               | Cultivated<br>in 1982 | Cultivated<br>in 1992 | Cultivated in<br>1982 and 1992 |
|---------------|-----------------------|-----------------------|--------------------------------|
|               |                       | (Acres)               |                                |
| EI < 5        | 190,764,000           | 179,139,700           | 165,563,000                    |
| 5 <= EI < 8   | 71,913,800            | 63,381,800            | 58,739,200                     |
| 8 <= EI < 10  | 28,030,900            | 23,802,300            | 21,273,600                     |
| 10 <= EI < 15 | 35,624,200            | 28,849,300            | 25,423,700                     |
| 15 <= EI < 20 | 15,644,800            | 13,303,600            | 10,605,300                     |
| 20 <= EI < 25 | 8,089,800             | 5,935,700             | 4,925,700                      |
| EI > 25       | 16,132,300            | 12,049,700            | 9,433,300                      |
| Total         | 366,199,800           | 325,462,100           | 295,963,800                    |

Nationally, 44 percent of the land enrolled in CRP came from farms that retired more than 75 percent of their available farmland. While approximately 2300 counties had acreage participating in the CRP, about 25 percent of these counties contain nearly 80 percent of the total acreage enrolled in the program. What will happen to this land if contracts are not extended will depend on the economics of the various land use options, which are considerably affected by Federal commodity policy. More than just the annual returns to land and management, the economics of the various options must also include cost of conversion from the current to the new land use, and the loss of benefits gained from the CRP (eg. hunting leases, hay reserve).

The fate of the CRP can be divided into three major categories: do nothing (eg. let the contracts expire), continue the current CRP (extend the existing contracts), or modify the current program. Certainly the first two options are easily addressed. The third category of options

contains numerous alternatives, but most center around the idea of obtaining more benefits on fewer acres. Key to a smaller, more effective CRP is better targeting. From the onset of the program better targeting has been urged (3,4,5,6). Following the 1990 farm legislation acreage was enrolled based upon an environmental benefits index (EBI).

The EBI is composed of seven separate items of environmental importance including surface water quality, ground water quality, soil productivity, tree planting, hydrologic unit area demonstration project designation, conservation priority area designation, and the cost of the alternative means available for ameliorating environmentally adverse consequences. The virtues of the EBI as a targeting mechanism are linked to its ability to obtain higher benefit to cost ratios than previous bid selection strategies. However, Barbarika found that the average EBI for the land enrolled in the first four sign-up periods was greater than for the last three sign-ups

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periods. The land enrolled in the fifth through ninth sign-up periods, on the other hand, had a much lower EBI than the land enrolled in the final three sign-up periods. Thus, the use of the EBI may have obtained greater environmental benefits in the last three sign-ups than would have been obtained using the previous bid selection criteria for CRP. Unfortunately little can be said about the ability of the EBI to actually gain environmental benefits since the EBI is merely an index and does not provide a measure of the actual benefits achieved by enrolling acreage in the CRP.

Evaluating CRP alternatives without including an evaluation and comparison of other programs designed to achieve similar environmental goals, will lead to an inadequate assessment of the ability of Federal programs to achieve a certain level of benefits (environmental or other) for the desired level of expenditures. Several programs such as the Agricultural Conservation Program (ACP), Great Plains Conservation Program (GPCP) and others have been providing assistance to farmers for many years to reduce environmental consequences of agricultural production activities. The Food, Agriculture, Conservation and Trade Act of 1990, introduced several new conservation programs including: the Integrated Farm Management Program, Forest Stewardship, Agricultural Resource Conservation Demonstration Program, Agricultural Water Quality Protection Program, Environmental Easement Program and Wetlands Reserve to name a few. Each of these programs may attain conservation and environmental (C&E) benefits. Evaluating the benefits and costs of the CRP in absence of providing the same

measures for these other programs will certainly bias the CRP debate.

The CRP should also be analyzed as it was legislated, as a package and not an independent program. The CRP was one tool in the FSA85 Conservation Title to induce cropland owners to protect soil and water resources. To attempt to deal with the problems associated with soil degradation, the Highly Erodible Lands Conservation (HEL) subtitle (B) and the Conservation Reserve subtitle (D) were inextricably linked. The long term land retirement feature of the CRP would assist in reducing crop surpluses while idling land with a severe erosion problem. A bid system for enrollment and the threat of lost program benefits through the HEL subtitle were legislated to assist in controlling the cost of the CRP. The HEL subtitle was legislated specifically to provide a strong incentive for a more cost effective Conservation Reserve Program (CRP) (Pg. 300-303 Senate Report 99-145). The HEL compliance provision was intended to induce producers with highly erodible soils, which could not be economically farmed at an acceptable level of soil erosion, to bid their land into the CRP. This would increase the acreage offered for enrollment in the program and make bidding more competitive. Owners of highly erodible cropland were to have five years to meet conservation compliance requirements or put their land in the CRP. Because the emphasis of the CRP and the HEL subtitle is on highly erodible land, the definition of *highly erodible* will be of considerable importance to the debate and final outcome regarding the fate of the CRP.

Erosion has been traditionally measured as annual soil loss in tons per

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acre per year by the Universal Soil Loss Equation (USLE) and the Wind Erosion Equation (WEE). This approach to measuring soil loss reflects both relatively stable physical constraints (i.e. rainfall patterns, basic soil properties) and more variable management factors (tillage type and technique, crop rotation). Measuring soil erosion in this manner tends to hide the influence of the management factors which are generally under the direct control of the farm operator.

One method to separate physical characteristics of the soil and management factors has been to use the Soil Conservation Service's (SCS) land capability class and subclass system. However, this method has problems of interpreting those soils with erosion problems. For example, this method identifies those soils having an erosion problem as subclass e with classes ranging from 1 to 8. Subclass e identifies only those soils which have erosion as a predominant limitation, though soils in other subclasses may also have severe erosion problems. The classes 1 to 8 identify the degree of severity the erosion problem poses to continuous cultivation. Class 1 lands have no limitation while class 8 lands are severely limited.

Bills and Heimlich (1) devised an alternate approach to examine erosion potential and management factors. They separated the USLE into physical and managerial components of soil loss. The USLE takes the general form

$$A = RKLSCP$$

where: A is a computed average annual soil loss per unit area, usually expressed as tons per acre per year; R is the rainfall

and runoff factor accounting for the number of rainfall erosion index units in the average year; K the soil erodibility factor, measuring the soil loss rate per erosion index unit for the specific soil; LS the topographic factor, accounting for the effects of slope steepness and length; C the cover and management factor, accounting for the specific crop and management relative to tilled continuous fallow; and P the support factor, accounting for the effects of contour plowing, strip-cropping, or terracing relative to straight-row farming up and down the slope. The product RKLS represents a reference soil loss which is management neutral. The factors C and P reflect land management and the product CP has a theoretical range from 0 to 1. The amount of erosion that occurs increases as the value of CP increases for a specific field. The NRI was the original source for identifying *highly erosive and highly erodible* land. Bills and Heimlich, utilizing the 1977 NRI, originally identified roughly 33 million acres as *highly erosive*. This highly erosive land would erode by more than 5 tons per acre per year with any kind of cultivation. A further explanation describes the best possible cultivation as the "most restricted (crop) rotations and support practices (a CP value under 0.1). However, a footnote on the same page (pg 4.) reveals that "no-tillage technology, with adequate residues left on the field, could potentially reduce the minimum CP value to .05 for corn, grain, and close-grown crops. At present, (1983) only about 8.6 million acres or 2 percent of U.S. cropland, is planted with no-till systems (2)." No-till increased to over 24 million acres by 1991 (9) but the use of this technology was not described by level

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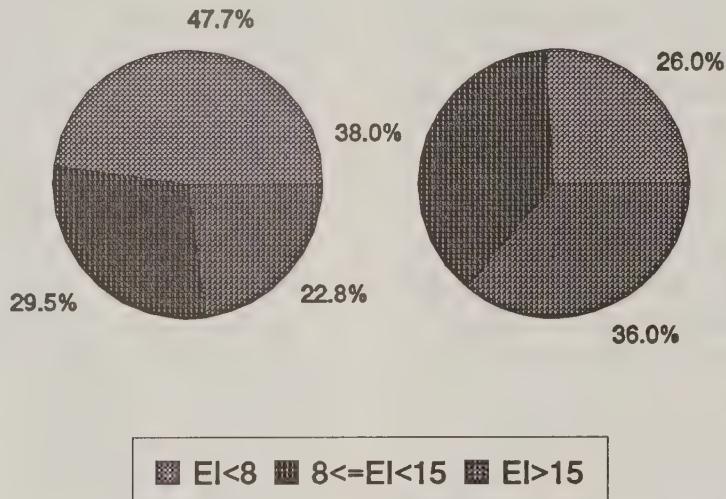
of soil erodibility. Thus, determining the effect of increased no-till and other technology on severe soil erosion was not determined. None the less, this increase is significant and may bear on redefining highly erodible and the need for incentives to induce producers to protect highly erodible cropland.

Lee and Goebel (8) adjusted the measure developed by Bills and Heimlich to include the soil loss tolerance of the soil ( $T$ ) and use a CP factor of .05 to define *highly erodible*. With this CP factor highly erodible land would have an Erodibility Index (EI) in excess of 20. That is an RKLS/ $T$  of 20 with a CP of .05 would produce a soil erosion rate of 5 tons per acre per year (assuming a  $T$  of 5 tons per acre per year). Defining highly erodible cropland as cropland that even with the best possible management practice (no-till) employed soil erosion would still exceed the natural level of soil regeneration would limit the targeted acreage to less than 18 million acres. These most highly erodible acres need immediate assistance. The CRP and other land retirement programs have reduced the acres in this category ( $EI > 20$ ) by 6 million acres between 1982 and 1992. However, 75 percent of the most highly erodible acres are still being used for the production of annual agricultural commodities, even though soil erosion will continuously reduce their productivity. Acreage eligible for the CRP included both highly erosive lands (cropland with an actual erosion problem) and highly erodible lands (cropland which may or may not have a current erosion problem but are inherently erodible). Thus, the CRP contains considerable acreage that is not highly erodible.

### Use of the NRI

Soil erosion saved by establishing a permanent cover on CRP acres was estimated at roughly 677 million tons using the 1994 CRP contract file. However, the estimates from the NRI indicate only 394 million tons of soil savings. Several reasons might create a difference between the NRI and CRP estimates of soil savings. First, the NRI estimates erosion at a specific point in a field. The soil type and characteristics for that point is used to estimate the level of erosion for a specific farm field while the predominant soil in the field was used to calculate erosion for the CRP. Second, the CRP erosion levels may include estimates without actual field visits. Estimates of erosion rates before conversion of a field to the CRP permanent cover was often made in county office during enrollment. The CP factor was estimated based upon the perceived cropping practices employed. This perception may have differed from the practices actually employed. Third, the NRI is a sample of the land base and not of CRP fields. Thus the NRI sample may not be a representative sample of CRP acres. For instance, the 1993 survey of CRP participants by the Soil and Water Conservation Society selected a five percent sample of CRP contracts. Soil Conservation Service employees collected soil characteristic data for each contract. Analyzing the data, Osborn identified the distribution of acres by erodibility index (7). Using the NRI to create the same EI distribution of acres reveals considerable discrepancies (Figure 1).

**Figure 1. Erodibility of CRP Acres  
1992 NRI**



The distribution of acres by EI found by Osborn in the SWCS survey would certainly produce higher rates of soil savings (when the land is retired) than the distribution of acres found in the NRI (assuming management was similar). Comparing the distribution of CRP acreage across 5 ton increments of soil savings found in the CRP contract file and the NRI produces a similar distribution (Figure 2). However, the NRI indicates that more than three times as many acres enrolled in the CRP have yielded erosion savings of less than five tons per acre than are identified in the CRP contract file. This difference in the allocation of the acreage accounts for the majority of the discrepancy of tons of soil saved annually between the NRI and CRP contract file.

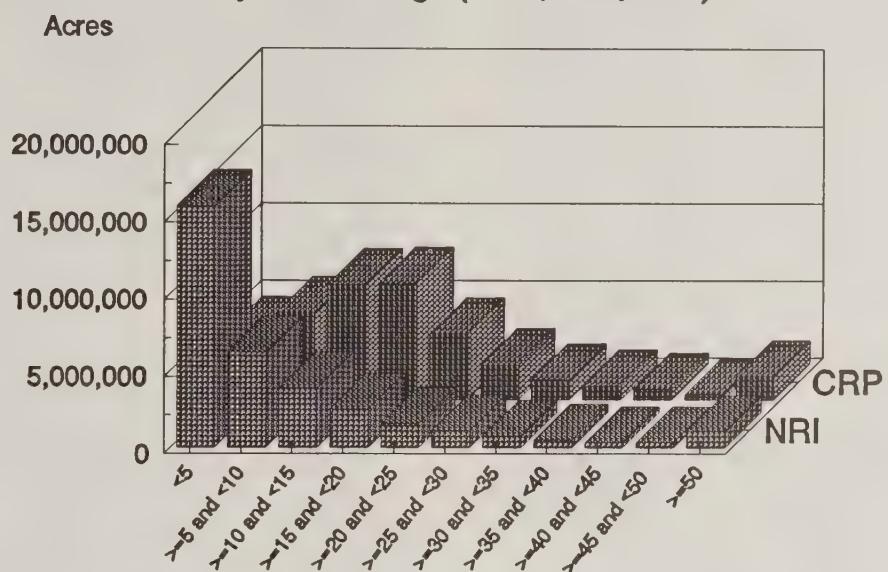
The impact of the difference in distribution of acreage by erosion savings can be better illustrated by providing a distribution of total tons of soil erosion saved by each increment of soil savings (Figure 3). The nearly 15 million acres

the NRI indicates are in the CRP having less than 5 tons per acre soil savings produces very little total soil savings and thus the CRP contract file has a greater total soil savings than the NRI in every other soil savings category.

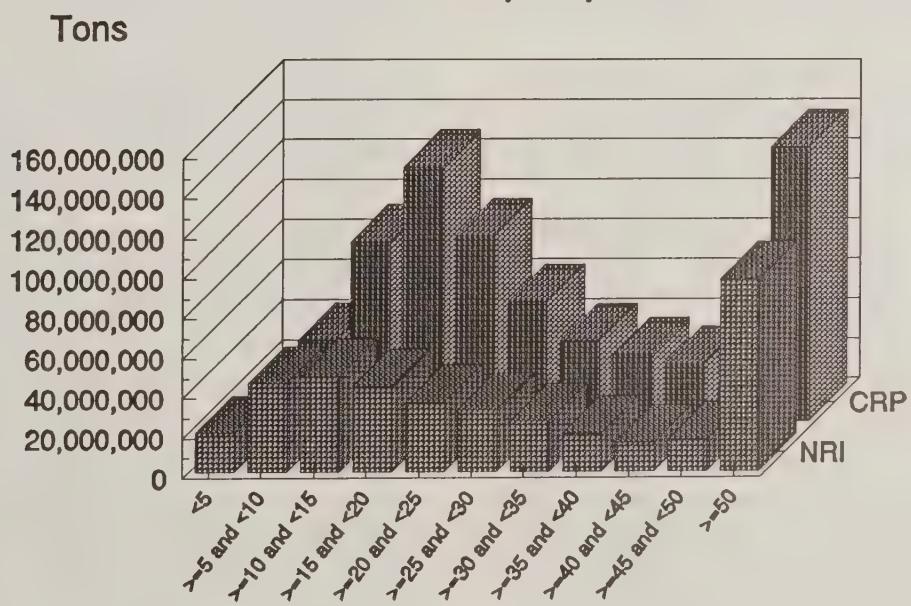
More important than the total tons of soil saved and the distribution of acreage by EI is the distribution of management (CP) by EI category. That is, are the best management practices occurring on the most highly erodible lands, and did the CRP enroll the most highly erodible land where the farm operator had the best soil conservation management. Results on this comparison are mixed.

The 1992 NRI was used to analyze changes in erosion and management levels between 1982 and 1992. Variables examined include water and wind erosion, total erosion index, the C factor, the P factor, and the product C\*P. These variables were analyzed for four regions and the United States. The four regions and the states comprising them are :

**Figure 2 . Acreage Distribution  
By Soil Savings (Tons/Acre/Year)**



**Figure 3 . Soil Savings  
Total Vs. Tons/Acre/Year**



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Midwest - Iowa, Minnesota, and Missouri; Mountain - Colorado, Idaho, Montana, New Mexico, and Washington; Northern Plains - Kansas, Nebraska, North Dakota, and South Dakota; and Southern Plains - Oklahoma and Texas. The set of variables was examined for seven land uses within the four regions. The land uses are: (1) cultivated land - land cultivated in both 1982 and 1992; (2) CRP - land that has been enrolled in the CRP; (3) continuous corn - land planted to corn for the three years preceding and including 1982 and the three years preceding and including 1992; (4) continuous wheat - land planted to wheat for the four years preceding and including 1982 and the four years preceding and including 1992; (5) continuous soybeans - same as for corn but regarding soybeans; (6) continuous cotton - same as for corn but regarding cotton; (7) corn-soybean rotations - any combination of corn and soybeans for the four years preceding and including the years 1982 and 1992.

These land use categories were used to compare erosion index's and CP levels. The erosion index and CP levels were separated into five different classes. Erosion index classes consisted of EI < 8, 8 < = EI < 10, 10 < = EI < 15, 15 < = EI < 20, and EI > 20. CP ranges included CP < 0.1, 0.1 < = CP < 0.2, 0.2 = CP < 0.3, 0.3 < = CP < 0.5, and CP > 0.5. Acreage was aggregated using the expansion factor based on EI class first then CP class. This resulted in a matrix of EI versus CP for both 1982 and 1992 data and changes in acreage levels were then calculated and used in the analysis.

Reductions in soil erosion levels were expected given the concern over soil erosion and legislation enacted to reduce

soil erosion over the past decade. The 1992 NRI data indicates that total erosion declined from 1982 levels for all four regions on cultivated land. For all cultivated land, the Midwest region experienced a 21.0 percent decline in erosion during this period (saving over 95.8 million tons of soil per year) while erosion levels for the Mountain, Northern Plains, and Southern Plains regions fell 7.4 percent, 31.7 percent, and 14.8 percent, respectively. In addition, all land uses in all regions generally posted reductions in soil erosion between 1982 and 1992. Only soybean acreage in the Southern Plains and wheat in the Mountain region experienced an increase in erosion. However, erosion on soybean acreage in the Southern Plains accounted for less than 0.2 percent of erosion for all cultivated land in that region and wheat accounted for less than .008 percent of erosion in the Mountain region.

While total erosion fell, water and wind erosion levels for some cropping practices increased in several regions. In particular, the Southern Plains experienced rising levels of water erosion for all cultivated land, continuous wheat, corn, soybeans, and corn-soybeans rotations. Water erosion also rose on soybean acreage in the Northern Plains and cotton acreage in the Mountain region. Wind erosion levels increased in the Midwest on wheat and soybean acreage and on wheat acreage in the Mountain region. Table 2 shows the amount of erosion from water and wind, average total erosion index, mean C and P factors, mean C\*P factor, and total acreage by region and crop use.

The Conservation Reserve Program (CRP) reduced erosion levels on acreage enrolled in the program. Examining the

**Table 2. Comparison of Erosion, Erosion Index, and C and P factors.**

|                 | USLE       |            | WEQ        |            | EI    |       | C    |      | P    |      | C*P  |      | Acres         |
|-----------------|------------|------------|------------|------------|-------|-------|------|------|------|------|------|------|---------------|
|                 | 1982       | 1992       | 1982       | 1992       | 1982  | 1992  | 1982 | 1992 | 1982 | 1992 | 1982 | 1992 |               |
| Thousand Tons   |            |            |            |            |       |       |      |      |      |      |      |      |               |
| <b>Midwest</b>  |            |            |            |            |       |       |      |      |      |      |      |      |               |
| Cultivated      | 286,682.00 | 218,578.00 | 170,044.00 | 142,353.00 | 6.35  | 6.30  | 0.32 | 0.26 | 0.95 | 0.93 | 0.30 | 0.25 | 48,647,452.00 |
| CRP             | 60,497.00  | 3,065.00   | 16,705.00  | 628.00     | 14.21 | -     | 0.24 | 0.02 | 0.93 | 0.99 | 0.23 | 0.02 | 5,547,903.30  |
| Wheat           | 204.00     | 155.00     | 307.00     | 314.00     | 7.74  | 7.74  | 0.21 | 0.19 | 0.97 | 0.95 | 0.20 | 0.18 | 63,655.20     |
| Corn            | 10,391.00  | 8,129.00   | 2,505.00   | 1,894.00   | 9.56  | 9.54  | 0.25 | 0.21 | 0.92 | 0.91 | 0.24 | 0.19 | 1,282,905.30  |
| Cotton          | 109.00     | 95.00      | 0.00       | 0.00       | 3.49  | 3.47  | 0.46 | 0.43 | 0.99 | 0.98 | 0.46 | 0.42 | 354,964.10    |
| Soybeans        | 2,129.00   | 1,905.00   | 59.00      | 67.00      | 1.38  | 1.38  | 0.49 | 0.42 | 1.00 | 1.00 | 0.49 | 0.42 | 32,988.60     |
| Corn-Soy        | 148,524.00 | 110,566.00 | 7,653.00   | 4,799.00   | 5.30  | 5.26  | 0.34 | 0.27 | 0.95 | 0.94 | 0.32 | 0.26 | 23,657,913.70 |
| <b>Mountain</b> |            |            |            |            |       |       |      |      |      |      |      |      |               |
| Cultivated      | 96,131.00  | 83,148.00  | 231,635.00 | 220,436.00 | 11.54 | 11.52 | 0.30 | 0.28 | 0.99 | 0.98 | 0.30 | 0.28 | 28,179,125.00 |
| CRP             | 23,120.00  | 5,875.00   | 62,667.00  | 13,966.00  | 12.20 | -     | 0.29 | 0.07 | 0.98 | 1.00 | 0.29 | 0.07 | 7,041,826.20  |
| Wheat           | 323.00     | 303.00     | 1,984.00   | 2,004.00   | 17.67 | 17.67 | 0.25 | 0.24 | 1.00 | 1.00 | 0.25 | 0.24 | 269,909.40    |
| Corn            | 818.00     | 747.00     | 7,645.00   | 4,290.00   | 16.10 | 16.10 | 0.40 | 0.37 | 1.00 | 1.00 | 0.40 | 0.37 | 385,686.70    |
| Cotton          | 5.00       | 5.00       | 124.00     | 56.00      | 19.74 | 19.74 | 0.56 | 0.65 | 1.00 | 1.00 | 0.56 | 0.65 | 6,577.70      |
| N. Plains       |            |            |            |            |       |       |      |      |      |      |      |      |               |
| Cultivated      | 202,691.00 | 165,277.00 | 258,624.00 | 149,937.00 | 6.72  | 6.68  | 0.25 | 0.22 | 0.92 | 0.90 | 0.24 | 0.20 | 72,491,809.60 |
| CRP             | 30,743.00  | 3,847.00   | 45,382.00  | 3,610.00   | 9.66  | -     | 0.22 | 0.03 | 0.93 | 0.97 | 0.21 | 0.03 | 8,947,489.00  |
| Wheat           | 5,493.00   | 5,235.00   | 6,382.00   | 4,685.00   | 5.24  | 5.22  | 0.20 | 0.21 | 0.86 | 0.80 | 0.17 | 0.17 | 2,189,085.30  |
| Corn            | 10,388.00  | 8,088.00   | 6,646.00   | 6,083.00   | 6.31  | 6.31  | 0.22 | 0.18 | 0.99 | 0.99 | 0.22 | 0.18 | 3,343,622.10  |
| Soybeans        | 15,054.00  | 14,347.00  | 4.00       | 0.00       | 2.19  | 2.19  | 0.30 | 0.30 | 1.00 | 1.00 | 0.30 | 0.30 | 6,477.70      |
| Corn-Soy        | 33,795.00  | 26,444.00  | 11,574.00  | 11,264.00  | 6.12  | 6.09  | 0.27 | 0.22 | 0.96 | 0.95 | 0.26 | 0.21 | 6,940,742.90  |
| S. Plains       |            |            |            |            |       |       |      |      |      |      |      |      |               |
| Cultivated      | 90,642.00  | 92,327.00  | 323,596.00 | 260,625.00 | 8.07  | 8.05  | 0.29 | 0.29 | 0.92 | 0.92 | 0.26 | 0.27 | 34,984,005.00 |
| CRP             | 9,968.00   | 1,643.00   | 97,757.00  | 6,294.00   | 11.63 | -     | 0.31 | 0.04 | 0.91 | 0.99 | 0.28 | 0.04 | 5,158,466.50  |
| Wheat           | 18,955.00  | 20,980.00  | 21,421.00  | 12,974.00  | 6.83  | 6.79  | 0.16 | 0.18 | 0.89 | 0.91 | 0.14 | 0.16 | 8,819,774.00  |
| Corn            | 514.00     | 546.00     | 855.00     | 612.00     | 7.44  | 7.44  | 0.28 | 0.32 | 0.98 | 0.98 | 0.27 | 0.31 | 239,110.00    |
| Cotton          | 8,266.00   | 8,087.00   | 81,598.00  | 76,001.00  | 2.25  | 2.24  | 0.38 | 0.42 | 0.95 | 0.98 | 0.37 | 0.41 | 100,632.90    |
| Soybeans        | 397.00     | 438.00     | -          | -          | 12.48 | 12.48 | 0.60 | 0.60 | 0.84 | 0.84 | 0.50 | 0.50 | 2,544,853.20  |
| Corn-Soy        | 968.00     | 1,055.00   | 950.00     | 701.00     | 6.02  | 6.02  | 0.31 | 0.35 | 0.97 | 0.98 | 0.30 | 0.34 | 358,020.60    |

Source: 1992 National Resources Inventory

mean EI's between CRP acreage and other cropping practices indicates that land enrolled in the CRP was generally more highly erodible than land cultivated in each of the regions. In addition, CRP acreage in all regions had mean EI's greater than 8 and thus could be classified as "highly erodible". In contrast, cultivated land generally would be considered as not highly erodible. The main exceptions were the Mountain region and cotton in the Southern Plains and corn in the Midwest. The erosion index levels for all the land categories in the Mountain region would be considered highly erodible. Although the EI for CRP acreage in the Mountain region was higher than the EI for all cultivated land it was lower than continuously planted land to wheat, corn, and cotton. Therefore the NRI data indicates that the CRP did remove more erodible cropland from production to some extent in all regions.

CRP acreage also showed the greatest change in soil savings comparing 1982 and 1992 levels and other land uses. Soil erosion on CRP acreage declined by 95 percent in the Midwest followed by declines of 92.4 percent, 87.9 percent, and 72.9 percent, respectively, in the Southern Plains, Northern Plains, and the Mountain regions. In the Midwest, CRP land was 11 percent that of cultivated land while soil erosion from CRP land was only 1.3 percent of erosion from cultivated land in 1992. Similar results were obtained for the other regions. Compared to soil erosion from cultivated land, erosion on CRP land was reduced from 22.9 percent in 1982 to 2.0 percent in 1992 in the Southern Plains while CRP acreage was only 14.7 percent that of cultivated acreage. In comparison, land dedicated to corn-soybeans in the

Midwest accounted for 48.1 percent of the erosion from cultivated land and 48.6 percent of the acreage and showed only a marginal improvement in reducing soil erosion. Wheat acreage in the Southern Plains exhibited a large improvement in soil erosion. Accounting for over 60 percent of soil erosion from cultivated land and 25.2 percent of the acreage in 1982 soil erosion on wheat acreage was reduced to only comprising 10.3 percent of erosion on cultivated land. In contrast, cotton acreage in the Southern Plains was 7.3 percent of the cultivated acreage but accounted for 22.2 percent of the erosion from cultivated land.

While soil savings were obtained through enrollment of lands in the CRP, a more important question is whether the CRP treated the most highly erodible lands. Also, the CRP soil savings accounted for only about 40 percent of the total soil savings occurring on cultivated cropland. Almost one-third of the erosion savings on cultivated land occurred on land cultivated continuously between 1982 and 1992. Since a soil's physical characteristics are relatively stable, improvement in reducing soil erosion on cultivated land must come from the management factors. The management factors associated with wind erosion were not available so the present discussion deals only with those factors affecting water erosion. The conservation factor (C) and cropping practice factor (P) of the USLE comprise those factors that a producer has control over to affect soil erosion. In general, the crop management improved (became less erosive) on the most erodible soils (Table 3). There was a net reduction in cultivated acres with a  $CP > 0.3$  nationally, for all levels of

**Table 3.** EI versus CP, Difference Between 1982 and 1992, Cultivated Acreage, Acres

|                 | CP<0.1       | 0.1<=CP<0.2   | 0.2<=CP<0.3   | 0.3<=CP<0.5     | CP>0.5         | Total       |
|-----------------|--------------|---------------|---------------|-----------------|----------------|-------------|
| <b>Total US</b> |              |               |               |                 |                |             |
| EI<8            | 5,750,600.00 | 15,621,400.00 | 18,754,200.00 | (37,493,800.00) | (2,312,200.00) | 320,200.00  |
| 8<=EI<10        | 449,200.00   | 997,000.00    | 366,800.00    | (1,759,700.00)  | (127,600.00)   | (74,300.00) |
| 10<=EI<15       | 768,200.00   | 993,800.00    | 369,600.00    | (1,596,100.00)  | (593,900.00)   | (58,400.00) |
| 15<=EI<20       | 387,300.00   | 603,100.00    | 24,400.00     | (763,000.00)    | 357,100.00     | 105,300.00  |
| EI>20           | 710,300.00   | 1,032,400.00  | (105,200.00)  | (1,359,500.00)  | (360,200.00)   | (82,200.00) |
| Total           | 8,065,600.00 | 19,247,700.00 | 19,409,800.00 | (42,972,100.00) | (3,751,000.00) | 0.00        |
| <b>Midwest</b>  |              |               |               |                 |                |             |
| EI<8            | 1,036,973.20 | 2,261,628.80  | 7,468,238.40  | (10,238,433.30) | (461,307.70)   | 67,099.40   |
| 8<=EI<10        | 70,366.10    | 191,243.20    | 59,188.20     | (315,386.40)    | (300.00)       | 5,111.10    |
| 10<=EI<15       | 311,153.30   | 207,565.00    | 86,132.80     | (624,684.20)    | (10,977.70)    | (30,810.80) |
| 15<=EI<20       | 156,854.50   | 149,310.00    | (25,622.00)   | (300,186.80)    | (4,533.30)     | (24,177.60) |
| EI>20           | 384,764.00   | 323,197.30    | (110,754.80)  | (599,506.50)    | (4,922.10)     | (17,222.10) |
| Total           | 1,960,111.10 | 3,132,944.30  | 7,477,182.60  | (12,078,197.20) | 492,040.80     | 0.00        |
| <b>Mountain</b> |              |               |               |                 |                |             |
| EI>8            | 2,853.60     | 240,905.00    | (36,734.80)   | (24,836.30)     | (153,321.00)   | 28,866.50   |
| 8<=EI<10        | (33,044.30)  | 31,355.70     | 131,689.40    | (43,737.10)     | (87,310.40)    | (1,066.70)  |
| 10<=EI<15       | 37,843.80    | 285,693.10    | (155,313.30)  | (40,968.40)     | (126,921.80)   | 333.40      |
| 15<=EI<20       | 58,166.60    | 124,210.00    | (84,021.50)   | 90,032.70       | (208,854.40)   | (20,466.60) |
| EI>20           | 76888.4      | 257,379.80    | 1,484.80      | (79,262.40)     | (264,157.20)   | (7,666.60)  |
| Total           | 142,708.10   | 939,523.60    | (142,895.40)  | (98,771.50)     | (840,564.80)   | 0.00        |

Table 3. Continued

|                        | CP<0.1         | 0.1<=CP<0.2    | 0.2<=CP<0.3  | 0.3<=CP<0.5     | CP>0.5       | Total       |
|------------------------|----------------|----------------|--------------|-----------------|--------------|-------------|
| <b>Northern Plains</b> |                |                |              |                 |              |             |
| EI<8                   | 3,361,763.80   | 8,010,016.50   | 1,942,513.00 | (13,189,811.70) | 18,128.30    | 142,609.90  |
| 8<=EI<10               | 345,430.10     | 510,931.40     | (72,118.30)  | (846,454.10)    | 6,277.80     | (55,933.10) |
| 10<=EI<15              | 286,440.90     | 412,142.20     | (84,054.20)  | (633,050.80)    | (755.50)     | (19,277.40) |
| 15<=EI<20              | 115,409.80     | 157,466.10     | (31,611.10)  | (272,175.80)    | 0.00         | (30,911.00) |
| EI>20                  | 66,366.00      | 219,220.50     | (101,899.30) | 219,664.50      | (511.10)     | (36,488.40) |
| Total                  | 4,175,410.60   | 9,309,776.70   | 1,652,830.10 | (15,161,156.90) | 23,139.50    | 0.00        |
| <b>Southern Plains</b> |                |                |              |                 |              |             |
| EI<8                   | (874,562.40)   | (1,194,926.40) | 1,500,226.00 | 1,218,049.50    | (624,108.70) | 24,678.00   |
| 8<=EI<10               | (91,299.70)    | (82,988.10)    | 68,110.80    | 478,352.70      | 57,244.30    | (1,100.00)  |
| 10<=EI<15              | (91,966.30)    | (342,786.80)   | 205,054.60   | 632,288.70      | (414,656.80) | (12,066.60) |
| 15<=EI<20              | (69,610.90)    | 5,855.60       | 55,944.20    | 126,910.60      | (123,244.30) | (4,144.80)  |
| EI>20                  | (59,877.60)    | (39,844.30)    | (229,422.30) | (122,331.80)    | 444,109.40   | (7,366.60)  |
| Total                  | (1,187,316.90) | (1,654,690.00) | 1,599,913.30 | 1,902,749.70    | (660,656.10) | 0.00        |

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erodibility. The distribution of CRP enrolled acreage by CP and EI classes was similar to the change in acreage which occurred on cultivated cropland<sup>3</sup> (Table 4).

The distribution of acreage by EI and CP supports the argument that all programs which act to control erosion should be compared with the CRP to evaluate the effectiveness and efficiency of obtaining erosion reduction and environmental benefits. For land with a high EI and high CP the appropriate policy question is, what policy instrument will induce the greatest change in CP for the least cost. Certainly those instruments which most effectively induce the greatest change in management (support the greatest reduction in CP) on the highest EI lands will have the greatest impact on both soil erosion and the adverse consequences of soil erosion. Nationally, a net loss in acreage cultivated with more erodible practices ( $CP > .3$ ) occurred between 1982 and 1992. Most important is that the loss of acreage in these categories occurred on cropland considered very highly erodible  $EI > 20$  (Figure 4).

For land enrolled in the CRP, the CP factor is being reduced to .01 for grass cover and .005 for trees. To obtain the greatest soil savings, the CRP would perform best if most of the acreage enrolled were from lands managed with a  $CP > .5$ . To protect the soil resources the CRP would perform best by enrolling lands that have an  $EI > 20$ . And, to both protect soil resources and obtain the largest soil loss reductions the CRP would enroll lands with a  $CP > .5$  and  $EI > 20$ .

The NRI indicates that the CRP was considerably short of both goals (Figure 5). More than 20 percent of the land enrolled in the CRP had an  $EI < 8$  and a  $CP < .2$ . This land is not considered highly erodible and will offer little soil loss savings. However, these lands may provide other environmental and conservation benefits (e.g. wildlife enhancement, ground water protection) which are not directly associated with their erodibility or past level of actual soil loss.

Comparing acreage enrolled in the CRP to that acreage cultivated in 1982 shows that the CRP did a better job of attracting highly erodible land than just examining the CRP acreage distribution. The CRP enrolled more than 20 percent of land cultivated in 1982 that had a EI greater than 10. More specifically the NRI indicates that over one-third of the most highly erodible land ( $EI > 20$ ) was enrolled into the CRP. In addition, Table 5 shows that as EI increased the percentage of land cultivated in 1982 and enrolled in the CRP also rose.

The 1992 NRI represents the fourth inventory of the national resources. Of significance in this inventory is the linkage to previous inventories so as to measure change in the resource base over time. This is important for measuring the affect of changing technology on the resource base. That is, the resource base is constantly changing. New technology (eg. equipment, plants, cropping systems) and the expanded adoption of past technology occurs continuously. Before the impacts

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<sup>3</sup> CRP acreage is not included in cultivated acreage.

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**Table 4.** EI versus CP, Difference Between 1982 and 1992, CRP Acreage, Acres

|                 | CP<0.1        | 0.1<=CP<0.2    | 0.2<=CP<0.3    | 0.3<=CP<0.5     | CP>0.5         |
|-----------------|---------------|----------------|----------------|-----------------|----------------|
| Total US        |               |                |                |                 |                |
| EI<8            | 24,220,900.00 | (4,662,700.00) | (7,689,000.00) | (10,122,500.00) | (1,746,700.00) |
| Midwest         |               |                |                |                 |                |
| EI<8            | 4,095,302.50  | (1,050,348.10) | (1,237,558.50) | (1,796,384.90)  | (11,011.00)    |
| Mountain        |               |                |                |                 |                |
| EI<8            | 4,328,600.10  | 160,082.50     | (1,589,770.40) | (2,489,458.60)  | (409,453.60)   |
| Northern Plains |               |                |                |                 |                |
| EI<8            | 7,154,359.20  | (1,666,168.10) | (2,961,460.80) | (2,533,230.30)  | 6,500.00       |
| Southern Plains |               |                |                |                 |                |
| EI<8            | 3,658,361.90  | (1,250,572.30) | (511,364.40)   | (822,418.40)    | (1,074,006.80) |

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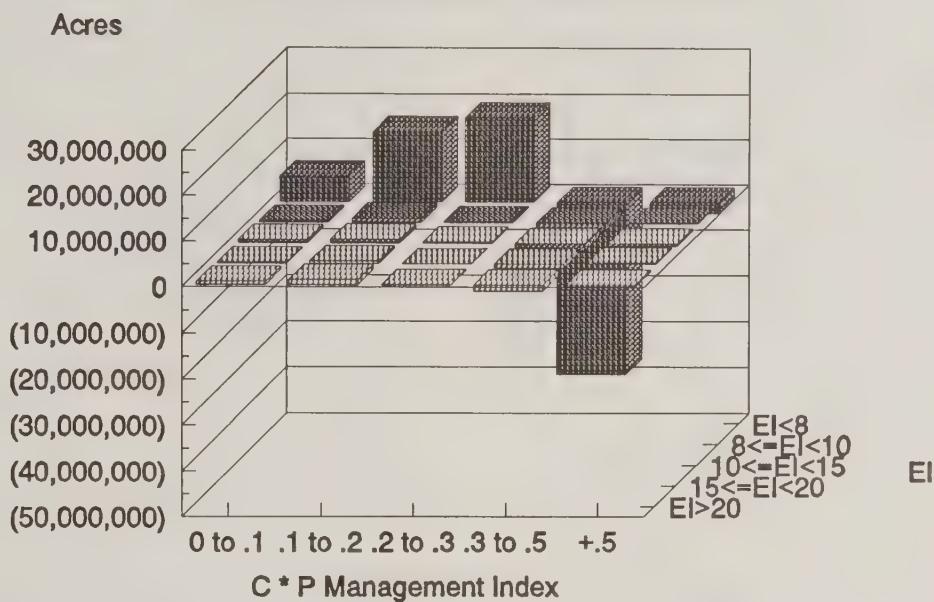
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**Table 5.** Percent of Acreage Enrolled Into The CRP Cultivated in 1982, Nationally.

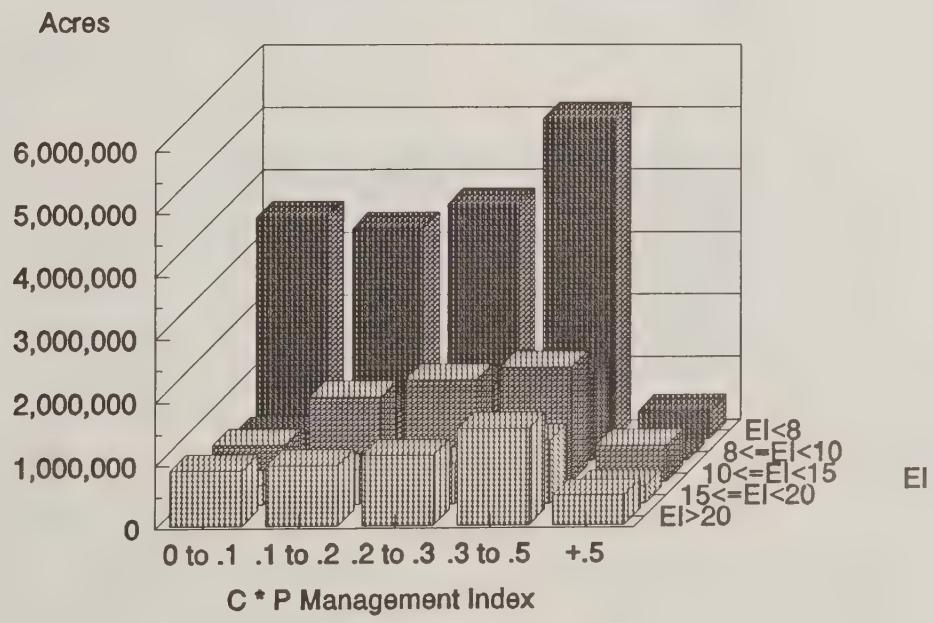
| EI \ CP  | <0.1 | 0.1 to 0.2 | 0.2 to 0.3 | 0.3 to 0.5 | 0.5+ | Total |
|----------|------|------------|------------|------------|------|-------|
| <8       | 27.7 | 8.3        | 6.5        | 4.6        | 5.9  | 7.2   |
| 8 to 10  | 27.5 | 16.2       | 18.9       | 19.5       | 11.3 | 18.9  |
| 10 to 15 | 27.4 | 22.9       | 25.2       | 21.2       | 26.3 | 23.6  |
| 15 to 20 | 25.3 | 22.3       | 25.1       | 29         | 28.6 | 26.1  |
| 20+      | 39.9 | 29.3       | 32.5       | 37.5       | 34   | 34.5  |
| Total    | 28.8 | 12.3       | 11         | 8.4        | 14.3 | 11.5  |

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**Figure 4. US - Cultivated Acreage**  
Difference Between 1992 and 1982



**Figure 5. Conservation Reserve Enrollment**  
Acres Enrolled By Category



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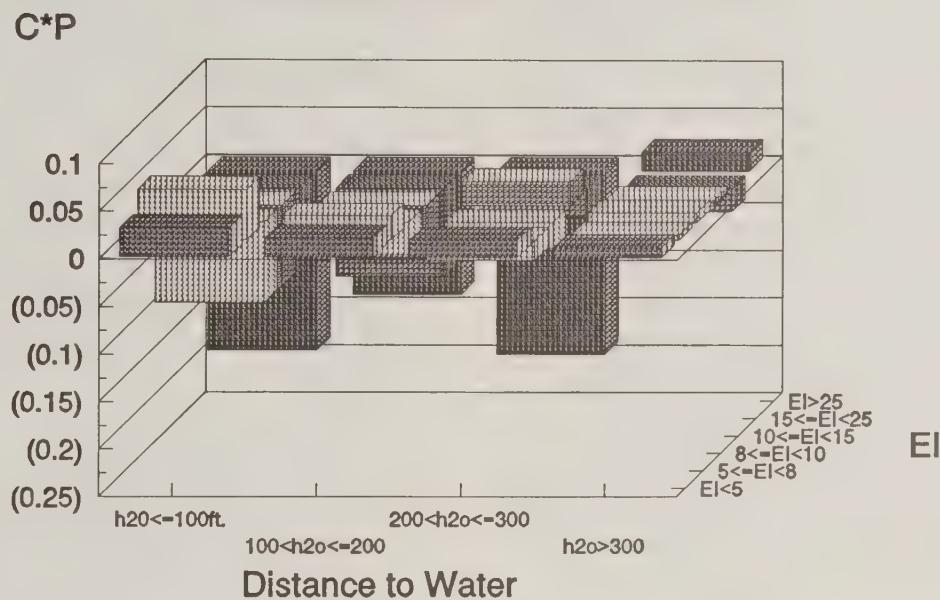
of a policy induced land use change can be estimated, the land use changes which occur outside of the specific policy must be known. This *baseline* of changing land use or changes in the natural resource baseline will establish what would have occurred had a specific policy not been implemented. Measures of the benefits of CRP must account for the changes that would have likely occurred in the absence of CRP. Thus, the NRI may be useful for setting the baseline from which the impact of policy changes and future land use changes can be determined.

Between 1982 and 1992 the CP factor decreased by nearly 13 percent on all U.S. cultivated land. Because soil erosion is the product of the physical characteristics of the soil and management (CP), the average soil erosion will be reduced at the same rate as the average reduction in CP. Thus if the average CP declines by 10 percent than the average rate of erosion will decline by 10 percent. If the change in CP occurs on lands with management that is less conservation oriented than the average (high CP) the erosion reduction will be greater than if the change occurs on land with better than average conservation management (low CP). The NRI indicates that 29 percent of the reduction in soil erosion occurred on land cultivated between 1982 and 1992. This reduction is direct result of a 13 percent reduction in the CP factor. As important as the average change for all land is the change in CP factor by erodibility index. Cultivated cropland with an EI less than 8 posted a 13.5 percent reduction in CP while the CP for cultivated cropland with an EI greater than or equal to 8 decreased by 10.6 percent.

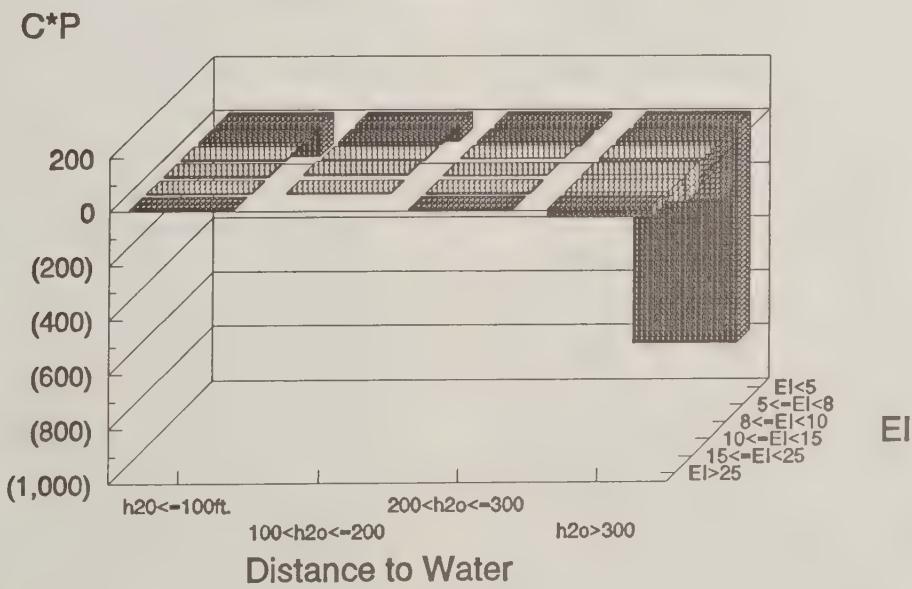
The change over time of the CP factor is important in identifying the true soil savings that may be attributed to the CRP. The change in crop management which occurred on all cropland could be expected to have occurred on CRP land as well. Thus, the 394 million tons of soil saved annually by the CRP must be adjusted downward for what would have occurred in the absence of the CRP.

The CRP has been able to create various environmental amenities such as improved water quality, and improved wildlife habitat. Can the NRI be used to provide an indication of the relative impact of the CRP on water quality and wildlife habitat. While the NRI contains no quantitative measures for either water quality or wildlife habitat data from the NRI may be useful in identifying the changes that may have occurred with land use which may have an impact on both environmental amenities. For instance, the NRI provides measures on changes in soil erosion as a result of changing land use and management factors. If this information is combined with the changes in crop management by distance from water, the effect of the land use changes on abating soil delivery to water may be observed. Figure 6 illustrates the net change in CP factor by erodibility index, CP factor and distance to water for the Southern Plains while Figure 7 provides the net change in land use by CP factor and distance to water for the same region.. To gain the largest surface water quality benefits a reduction in the CP factor on the most highly erodible soils within the closest proximity to water would be targeted. Between 1982 and 1992 the NRI indicates that the CP factor on the most erodible land closest to water was reduced

**Figure 6. Southern Plains - CP Factor  
Difference Between 1992 and 1982**



**Figure 7. Southern Plains - Acreage  
Difference Between 1992 and 1982**



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by almost .2. However, while the largest CP change occurs on the land which can provide the greatest water quality benefit, the change occurs on the fewest of these acres. The pattern is consistent for CRP acres. Thus, better gains in water quality could be gained by targeting programs to change land use on the most erodible soils with the closest proximity to water.

A similar analysis could be performed for the variation in cover. That is, land cover that has considerable diversity tends to provide better wildlife habitat. Thus, using the NRI to estimate the changing land diversity resulting from the CRP versus that which has occurred without the CRP would provide a relative measure of the impact of the CRP on wildlife.

### Summary

The NRI has considerable potential for analyzing the impact of land use policies such as the CRP over time. We have identified several strong differences between performance of the CRP as determined from the CRP contract file and the NRI data. Some of these differences are too large to ignore or to explain with possible reasons, such as the difference in the total erosion savings of the program. Also, some of the findings of the NRI appear counter intuitive such as the increasing CP factor on wheat acreage in the Southern Plains. These areas should be further researched to determine the cause of the discrepancy.

The analysis of the NRI has indicated that farm operators have made great strides in improving the conservation orientation of their practices. This is not an insignificant finding particularly as we approach the 1995 farm bill debate. Additional legislation, especially

regulatory legislation, may be unwarranted in light of the current trend in reducing CP factors. The NRI clearly shows the need for better targeting of assistance to obtain specific objectives on specific acres.

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# **Using the National Resources Inventory for Ecological Assessments in a Regional Decision Support System for the Chesapeake Bay**

**By Margaret Stewart Maizel, Tom Iivari, Darlene Monds, George Muehlbach, Paul Baynham, Jennifer Zoerkler and Paul Welle, with the assistance of the Chesapeake Bay Decision Support System Working Group\***

## **Background**

In order to manage all of our resources, we need basic networks and information systems relating the nature and distribution of ecosystems and their responses to stress and change. To develop these systems, we need working definitions of ecosystems and supporting inventories of the physical and biological components that comprise them. We also need to understand ecological patterns and processes and their interrelationships with the social, economic, physical and biological systems within and around them. We must thus obtain better information about the distribution and interaction of organisms and their environments including species demographics, development and succession and the effects of human activities and land use as change agents upon those species and their ecosystems (20).

Multi-disciplinary and multi-organizational cooperative efforts in which scientists contribute to, and synthesize new knowledge as a result of working together on a common geographic area is a basic requirement in building the complex information systems described above. Comprehensive, integrated and hierarchically organized Geographic Information systems (GISs) are indispensable in providing the necessary framework supporting better understanding of complex spatial and temporal interrelationships in ecological landscapes.

Many of the data sets needed in GISs are already available and can be exceedingly rich in content. Before collecting new data, we have an obligation to explore existing information systems in integrated environments, since integrating them under proper conditions always leads

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to new information not otherwise available. The National Resources Inventory (NRI) was originally conceived, and has continued to evolve, as a multi-resource inventory that serves as the federal government's principal source of information on the status, condition and trends of soil, water and related resources for the nation's non-federal and Indian lands (See for example, Resource Conservation Act (1972), Food Security Act (1985 and 1990)). It has been used extensively at the heart of a GIS-based cooperative study to identify priority watersheds where the potential for ground water contamination from farming systems is highest in the nation (8).

This report describes the institutional, multi-disciplinary and technical approach used by an expanded group of scientists and cooperators to transfer and extend a system of environmental indices used as screening tools at the national level in a hierarchical GIS framework to a more spatially precise regional assessment in the Chesapeake Bay drainage area. It illustrates ways in which the NRI can be integrated with existing point- and area-based as well as continuous spatial and non-spatial data to synthesize environmental indices. The use of these indices for priority ranking of watersheds to support targeting of cooperative regional efforts in the Bay for resource protection is illustrated. In addition, use of the NRI in concert with other spatially explicit information describing landscape settings and ecologically related resources is illustrated. The technical and institutional approaches used here are directly applicable to other regions of the United States and to other countries providing that similar soils, land use, cropping practices

and farm chemical use data, as well as weather information is available.

## Methodology

### *A Multi-disciplinary Cooperative Effort*

The national parent study framing this work was originally conducted among NCRI and three agencies of USDA: the Economic Research Service, the Soil Conservation Service and the Cooperative State Research Service of USDA (8). The Chesapeake Bay -- among those most valuable of estuaries of its kind in the world -- was determined to rank fourth among the 204 regional and sub-regional watersheds in the U.S. with the highest potential for ground water contamination from leaching pesticides (9). An expanded group of cooperators was formed to contribute to the development of the Chesapeake Bay Decision Support System (CBDSS). The CBDSS is a spatially explicit, hierarchical, (national, regional, sub-regional and local) evolving, multi-layer, comprehensive and coordinated decision support system. It is being built in response to a request by the six State Conservationists in Pennsylvania, Virginia, Maryland and the District of Columbia, New York, Delaware and West Virginia to describe agricultural systems in relation to landscape units, biological and natural systems; cultural resources; and social and economic characteristics and demographics of human communities in the watershed. Cooperating members of the CBDSS working group include the National Center for Resource Innovations - Chesapeake Inc., senior scientific staff at the NRCS Northeast National Technical Center, universities in the region; NRCS state offices, the Economic Research Service (ERS)/USDA and others. The institutional

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structure and plan for development and technology transfer of the CBDSS is shown in Figure 1.

The CBDSS working group operates on a principle of technology sharing. Each member brings distinct expertise, data and information systems to the program. The NRCS Northeast National Technical Center (NNTC) in Chester, PA provides specific data bases from NRCS, input into indices and coordinates technology transfer to the NRCS state offices. The Economic Research Service (ERS) of USDA is developing economic and other environmental indicators and providing specialized information systems to the project. Virginia Polytechnic Institute's Department of Agricultural Economics is assisting ERS. NCRI is building the spatial and attribute data bases together with index algorithms while assisting in coordinating the project. Penn State University is developing sensitivity analyses of the indices. The NRCS National Headquarters (NHQ) staff is translating the new spatial data bases and indices into the Geographical Resources Analysis Support System (GRASS) GIS for use within NRCS and building a user interface to the system for managers and technologists. Organizations denoted by square brackets are proposed future members of the working group.

Membership in the working group -- and the group's clientele -- is expected to evolve as the system changes to meet evolving kinds of application. Through a Memorandum of Understanding each member has access to all data bases on a 'beta' test basis in order to evaluate them for identified applications. The system is being incrementally transferred by the Working Group to NRCS State offices for

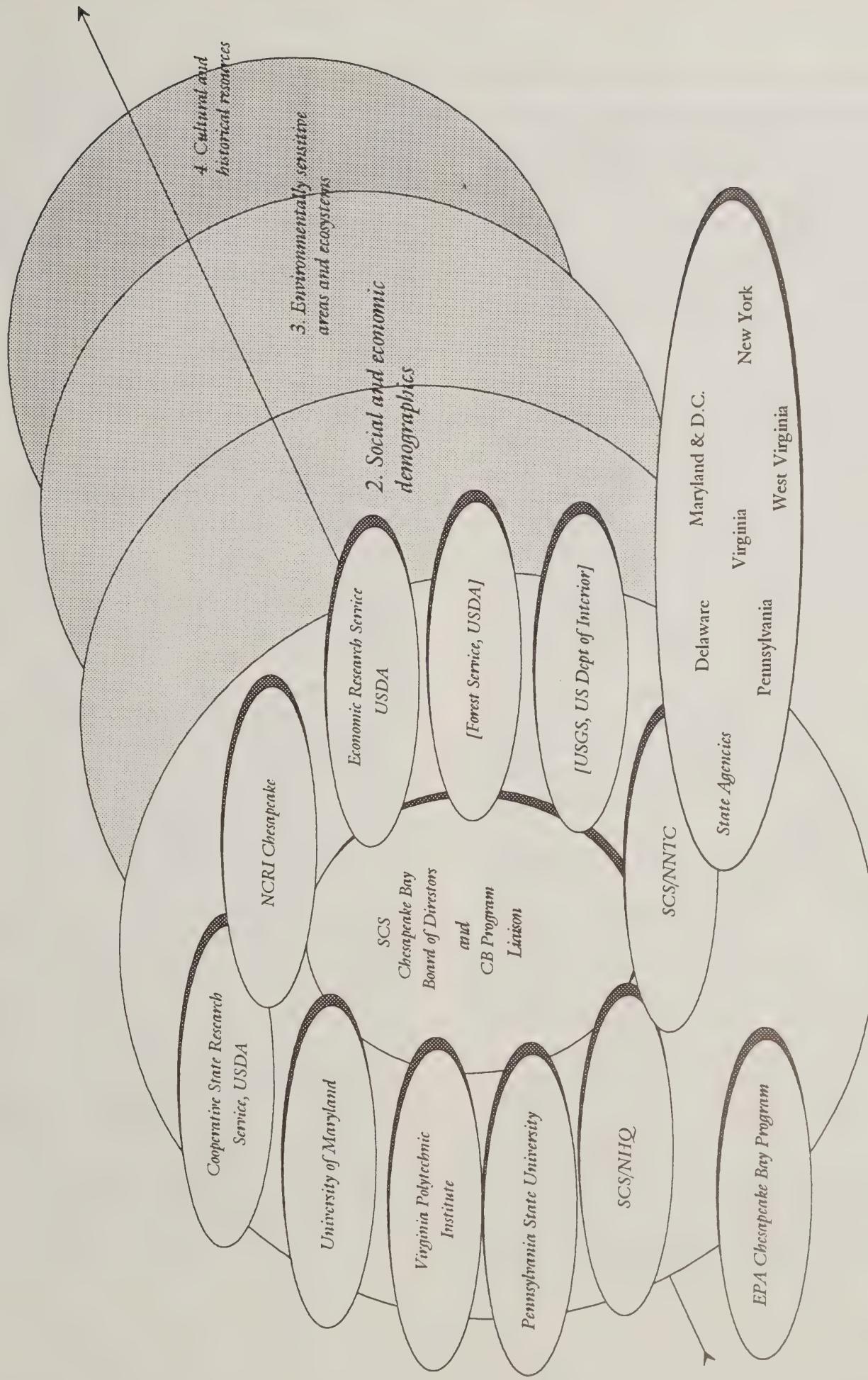
testing. When the decision support system has been transferred to each NRCS state office and examined for state level, as well as regional applicability, the technology and data will then be made available to state agencies and, as appropriate, the general public.

Initially built to describe agricultural landscapes in the watershed, the system is designed to be expanded to accommodate cultural and historic resources, environmentally sensitive areas, demographics, population and economic infrastructure. Time-related factors will be added as the system becomes more specific. A recent addition to the system is a sub-regional pilot project to characterize the economic and sociological characteristics of farm and nonfarm sectors of human communities in the rural through urban continuum in southeastern Pennsylvania. A more recently instituted effort will link the nutrient production of some 2 million septic systems in the watershed to the physiographic units in which they are located and thence to surface and ground water resources and the Bay itself.

#### **Environmental Indices and Data Bases**

Early in development of the project, it was decided that only existing data bases which are consistent for the region, are easily obtained and are easily integrated into a GIS would be used. Thus the general (regional) scale of the CBDSS which covers 42 million acres is effectively 1:250,000. Pilot projects at subregional scales (1:100,000 and 1:15,840-24,000) are being developed. One of the strengths of the NRI is its capability to be integrated with other data bases and information to build

# Institutional Model for CBDSS Development



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environmental indices and relate them to ecologically sensitive resources. Detailed descriptions of indices and data bases have been developed by the Chesapeake Bay Decision Support System Working Group. All of the indices reported here, with the exception of one, 'Q', apply to cropland only. Though derived from other data in addition to the NRI, all calculations are made at NRI points.

As these indices are used in increasingly larger scales (closer to the ground in the national to local hierarchy) the complexity of available information increases. At the point where watershed planning is based on 8-digit hydrologic units, other spatial data inevitably begins to replace the NRI (NCRI Chesapeake, unpublished data).

#### *(a) Ground Water Indices*

Indices developed for use at the national level are used only in a screening process (Kellogg, Maizel and Goss 1992). Time frames are long and factors used are generalized. The GWVIP is an example of such an index.

*The GWVIP.* The potential for pollution of ground water from pesticide use is the result of a combined interaction between pesticides, soils, climate, crop type and cover, farm practices and management systems. The national scale Ground Water Vulnerability Index for Pesticides (GWVIP), as simply a screening tool, accounts only for primary interactions between pesticides and soils as affected by average annual precipitation and irrigation resulting in the relative potential for pesticides to move below the root zone in a growing season.

Soils are classified into four leaching classes according to surface horizon depth,

organic matter content, K (or erodibility factor), and soil hydrologic group. Pesticides, classified into four leaching potentials according to their half-life, solubility, and organic carbon partitioning coefficient are distributed to soils through the crops-soils association in the NRI. As driven by average annual precipitation and soil permeability at the NRI point, the potential for leaching of pesticides below the root zone can be determined.

Sources and methods for integration of pesticide use data for 86 specific crops, average annual precipitation and to build the GWVIP at NRI sample points have been described (Kellogg, Maizel and Goss, 1992).

*The Ground Water Vulnerability Index for Excess Nitrate from Fertilizer (GWIN)* has also been thoroughly described (6).

Nitrate inputs from fertilizer use on specific crops (in this case only corn, wheat and cotton) was obtained from the National Agricultural Statistics Service's (NASS's) Cropping Practices Survey (CPS) data points. Calculations for nitrate content in crops removed and residue remaining in cover was transferred to NRI sample points by local area and by crop. Nitrogen budget balances due to fixation by legume crops previously grown at each NRI point were calculated and the index expressed as excess nitrate in pounds per acre available for leaching through the root zone as affected by average annual precipitation and soil permeability. This index is nutrient budget-based and is planned as a component of an overall nutrient budget which will eventually account for nitrates from animal waste, septic fields and atmospheric deposition in the Chesapeake watershed.

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### (b) Surface Water Indices

*Highly Erodible Cropland (EI > 8)* is cropland which, without crop cover and conservation practices, has the potential to erode at eight or more times the rate at which the soil would normally be replenished. This criterion is a primary determinant of eligibility for the Conservation Reserve as provided for in the 1985 and 1990 Farm Bill (17). Unlike the ground water indices, this index is calculated entirely at the NRI point from NRI and co-located SOI5 data.

*Erosion (USLE)* is used to estimate average annual soil loss in tons/acre/year at the NRI sample point level. This index provides input to a planned surface water potential for surface water and sediment transport/delivery to blue line streams in a GIS framework. This index is also entirely calculated at the NRI point.

*Surface water run-off (Q)* is that portion of precipitation that flows off an NRI sample point under certain conditions (SCS/USDA, 1986). For this index, Q is determined by land cover, soil hydrologic group, conservation practices, row crop slope, pastureland/rangeland condition, forest understory factors, urban lands permeability, conservation treatment and conservation needs as provided at the NRI-SOI5 sample point. This methodology was developed by Paul Welle, of NRCS/USDA (21) for this project. Surface water indices are being developed to accommodate run-off estimations for soluble nitrate and pesticides, and pesticides and other farm chemicals adsorbed to soils for transport modeling. Geographically distributed average annual rainfall, peak 24-hour precipitation (Five Year Rainfall Frequency Atlas, National Climate Data Center, NOAA) without orographic

correction, for the time being, is applied to each NRI sample point as previously described (10,22). This index is entirely calculated at the NRI sample point.

*Conservation Reserve enrollment benefits for water quality.* Crop-specific data for CRP enrollments by county was obtained from the Agriculture Stabilization and Conservation Service, USDA - up to the twelfth sign-up. County level CRP enrollment data were transferred to NRI sample points meeting CRP eligibility criteria through crop type (Tim Osborne, ERS/USDA personal communication and paper in preparation).

*NRI Polygon/Land Use and Cover Intersections for Finer Spatial Addressing.* Methods for using the NRI as a statistical point-sampled inventory in choropleth maps have been described (10). Integration of NRI polygons to gain finer spatial addressing has also been previously described (11). Briefly, NRI sample points are matched to NRI polygons through their county-MLRA-hydrologic unit 'geocodes'. Then, through their land cover classification, they are spatially sub-allocated within these NRI polygons to appropriate land cover types (1). Thirty categories of NRI cropland and pastureland uses are allocated to a single cropland/pastureland category. Six NRI horticulture categories are allocated to a single LUDA horticulture category and one NRI category including farmsteads, feeding operations and other land in farms is allocated to a single LUDA category containing confined feeding operations and other land in farm areas (11). For reference, all maps in this paper include federal lands and urban lands.

*Data Sources.* Cropping Practices Survey (CPS) data (1982) and nutrient

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budget calculations were provided by the Economic Research Service/USDA as described (6). The State Soil Geographic Data Base for six states was provided by NRCS/USDA (14). A high precision digital elevation model (DEM) was synthesized by NCRI from a 30 arc-second Digital Elevation Model (Defense Mapping Agency as provided by the Chesapeake Bay Program Office, Annapolis, MD). The DEM was then modified to incorporate National Ocean Survey zero elevation shoreline monumentation control and densified with 50,000 National Geodetic Survey (NGS) first and second order geodetic control points and elevation data for water bodies from TIGER files (1990). The control points were provided by the National Geodetic Survey, NOAA through a cooperative agreement with NCRI-Chesapeake.

LUDA (Aerial Photography-Based Land Use for 1972 through 1984; (1)) for the Chesapeake Bay states was acquired from USGS in GIRAS format. The National Wetlands Inventory (1:24,000) was obtained through the U.S. Fish and Wildlife Service, U.S. Dept. of the Interior. Eight-digit hydrologic unit boundaries (13) were provided to NCRI-Chesapeake by Ken Lanfear, U.S. Geological Survey, Water Resources Division, Reston, VA. They were modified by NCRI to accommodate 11-digit boundaries (SCS/USDA, 1992) completed by NRCS for Virginia and West Virginia. All layers were maintained as ARC/Info libraries.

*Expression of Indices in Maps Used in this Study.* Descriptions of indices in maps varies for this study. Maps shown here are of two kinds: (1) Percent area maps (for EI, GWVIP and GWIN where

a minimum cut-off applies to the index) and (2), ranges for average values of each NRI polygon (for USLE and Q in which area-weighted average values in NRI polygons are classed and displayed within numeric ranges).

*Calculations for Priority Ranking by Watershed.* Watershed- and ecosystem-based planning is becoming better recognized as a valuable basis for implementing conservation programs. The basis for establishing priorities for targeting technology, expertise, funds and research may vary, however, by program and by available resources. Priority ranking of 8-digit watersheds was developed in three ways to support these concerns. For all watersheds, NRI polygons intersected with land cover were aggregated as building blocks into 8-digit hydrologic units embodying the polygons.

1. Total acreage of cropland affected. The total acreage of affected cropland in each hydrologic unit was determined by summing the expansion factor for each NRI sample point to estimate the total acreage represented by each point meeting the criterion (e.g., minimum index value such as a GWVIP > 124). It should be noted that in the Chesapeake, 12 counties, primarily in the southeastern section of Pennsylvania in 1982 were inventoried at a density sufficient to provide county level reliability for acreages. Cropland acreages were sampled at a higher rate than other land uses. Even though cropland acreages in general may be more accurate than other land uses, the small size of some watersheds should be carefully considered in making

- acreage assessments and in using priority rankings.
2. Proportion of total non-urban, non-federal area affected. This was determined by summing the NRI sample expansion factors, multiplied by the index value and summing the product to the 8-digit watershed level. This number was then divided by the sum of all NRI sample points in the watershed to provide a percent area of the watershed.
  3. Proportion of total cropland affected. This calculation is the same as in (2) above, except that the denominator contains all cropland points in the watershed. Though there may be small amounts of cropland in a watershed, a high percentage of them may have a potential for environmental effects.

Watersheds were rank-ordered from high to low for each index and natural breaks in the rankings were used to group the 54 watersheds into three classes: High, Medium and Low.

## Results and Discussion

Of the 42 million acres of land comprising the Chesapeake Bay watershed, forestland covers 21.0 million acres or almost exactly 50 percent of the area. Cropland (8.18 million acres) is the second major land cover/use type, and pastureland (4.56 million acres) is the third major land cover type. Other principal land uses are divided among barren lands (275,700 acres), other lands (976,200) and rural transportation (28,700 acres). Federal lands amount to 2.9 million acres in the watershed. Urban lands amount to 2.6 million acres. Minor land uses include urban transportation, urban lands and

census water (SCS/USDA, 1984). While Anderson Level II classifications combine cropland and pastureland into one category, horticultural land uses and other agricultural uses are separately discriminated as are other agricultural lands (11).

*Ground Water Potentials for Contamination from Pesticide Use in the Chesapeake Watershed.* Of the 341 million acres of private and Indian lands in cropland in the U.S., 141 million, or 41 percent were determined to have the potential for ground water contamination from pesticide use (8). Of the 8.18 million acres in cropland in the Chesapeake Bay watershed, a higher percentage than the national average (55.6 percent, or 4.55 million acres) has a potential for ground water contamination.

Distribution of the five indices is shown in Figure 2 (A-E). The key to these figures is shown in Figure 2 and a key to watershed names and cataloging numbers is shown in Figure 2F. Watersheds with reference numbers 1 through 19 are in the Susquehanna River basin; reference numbers 20 through 27 are in the Delmarva Peninsula of Maryland; reference numbers 28 through 38 are in the Potomac River basin; and the remaining reference numbers (39 through 54) are in Virginia, draining to the Chesapeake directly.

The distribution of the GVVIP in the Chesapeake watershed is shown in Figure 2A. The percent area of cropland/pastureland areas in LUDA that is cropland with an index greater than 124 appears to be highest in the northwestern area of the Delmarva and in small areas associated with rivers draining to the Chesapeake in Virginia (the Lower

Rappahannock, Mattaponi, Lower Pamunkey and the central region of the Appomattox). Larger areas are found in the lower Susquehanna River basin, in central Pennsylvania and in central Maryland west of Baltimore. According to the 1982 NRI, the largest primary crop types (not counting crop rotations) in the entire watershed are corn (3.0 million acres or 37% of the cropland); soybeans (0.92 million acres or 11% of the cropland) and wheat (0.5 million acres or 6% of the cropland acres). Twenty-six pesticides were used on 2.3 million acres of corn (6.6% of the watershed area and 77% of the corn acreage) in the mid-1980's. Atrazine, with a large potential to leach is the most extensively used pesticide. Atrazine has, in fact, been detected at low levels, in nine surface water studies in the watershed (18).

*The Ground Water Potential for Contamination from Excess Nitrate from Fertilizer Use on Corn and Wheat in the Chesapeake Watershed.* The combined acreage in corn, wheat and cotton in the U.S. in 1982 was 194.8 million acres. Excess nitrate was found to potentially occur on 189.8 million acres or on 97% of these acres. The distribution of corn and wheat acreage with a GWVIN  $>0$  in the Chesapeake is shown in Figure 2B. Here, excess nitrate potentially occurs on 2.99 million acres or 85% of the corn and wheat acres planted. Unlike the GWVIP, this is less than the national average. No cotton was grown in the Chesapeake in 1982. The highest percentage of acres with excess nitrate are found in the Chester-Sassafras watershed in the Delmarva peninsula of Maryland, in the lower Susquehanna River basin, the central Susquehanna river basin and in central

Maryland west of Baltimore. Interestingly, 2.82 million acres of cropland in the Chesapeake have both GWVIP  $>124$  and a GWVIN calculation  $>0$ . This is expected to increase somewhat when the GWVIN is calculated for soybeans and all other crops grown in the watershed.

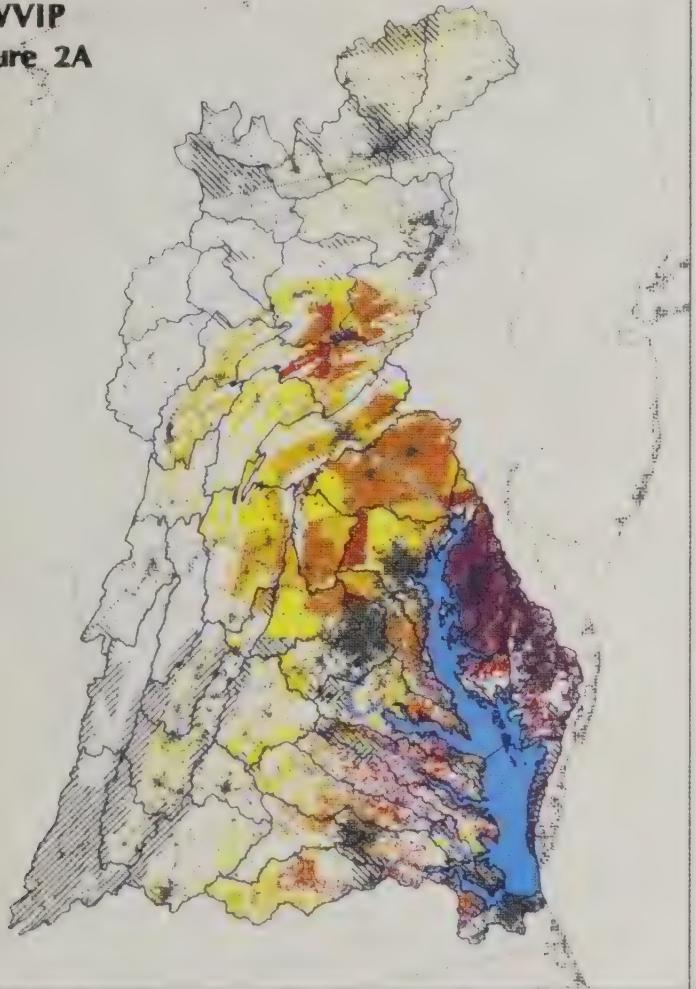
*Highly Erodible cropland (EI)* in the Chesapeake watershed is shown in Figure 2C. It is distributed differently from ground water indices. It is predominantly found in the central and lower regions of the Susquehanna River Basin, the upper Juniata, Raystown and lower Juniata River basin tributaries of the Susquehanna, the South Fork of the Shenandoah in the Potomac River basin, and the central Appomattox River watershed in Virginia.

*Erosion (USLE)* expressed in tons/acre/year is shown in Figure 2D. Erosion in the Chesapeake drainage is very broadly-based. Highest erosion rates are in the Lower Susquehanna River basin, the upper reaches of the Patuxent River, the Virginia Piedmont in the upper Rapidan River watershed and the Shenandoah River watershed. Rates in excess of 5 tons/acre/year are occurring on 5.32 million acres (65% of the cropland) in the watershed.

*Surface Water Run-off* on all non-urban, non-federal land in the watershed is shown in Figure 2E. Run-off in inches is highest in the Chester-Sassafras watershed in Maryland, the central Susquehanna River basin and its upper reaches and in the lower Shenandoah River drainage near the Potomac. The second highest rate of run-off occurs in central Maryland in the Lower Susquehanna and Susquehanna-Swatara watersheds. Run-off in Figure 2E is calculated only for non-urban, non-federal lands in the watershed. When

**GWVIP**

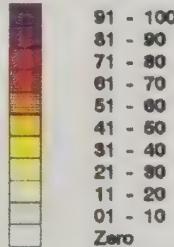
**Figure 2A**



**Figure 2.**

- A - GWVIP Percent Area With a GWVIP Greater Than 124 on Cropland
- B - GWIN Percent Area With a GWIN Greater Than Zero on Cropland
- C - EI Percent Area Highly Erodible Cropland (EI greater than or equal to 8)
- D - USLE Universal Soil Loss Equation
- E - Q Surface Water Runoff

Color Key for Percent Area Land Matching Criteria



91 - 100

81 - 90

71 - 80

61 - 70

51 - 60

41 - 50

31 - 40

21 - 30

11 - 20

01 - 10

Zero

Urban or Built-up Land  
Water

**NON MAPPING KEY**

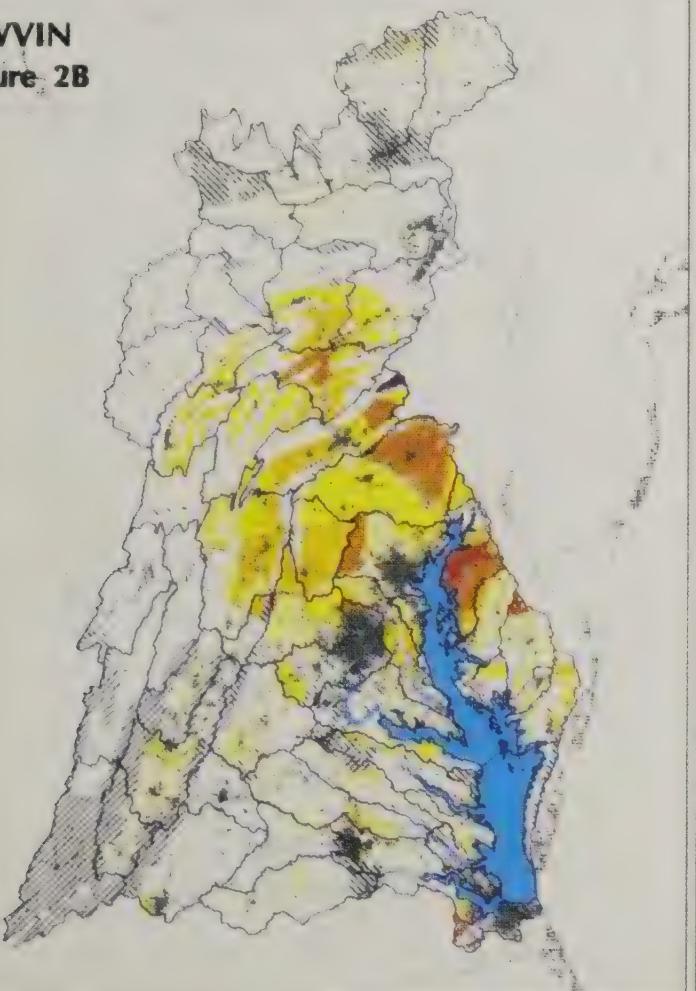
Federal Lands  
Non-Mapping

**BOUNDARY**

8-Digit Watershed  
State Line

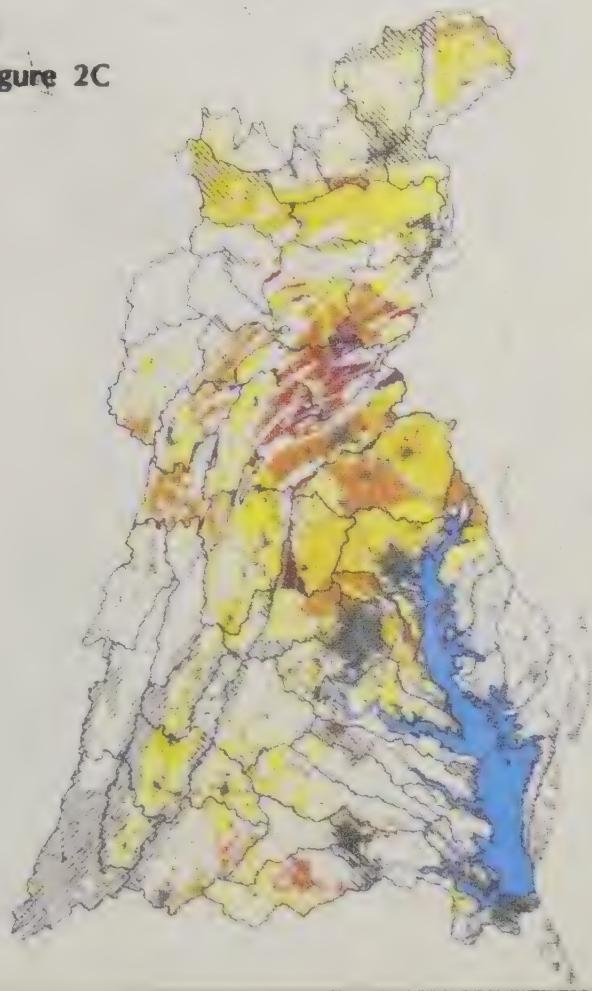
**GWIN**

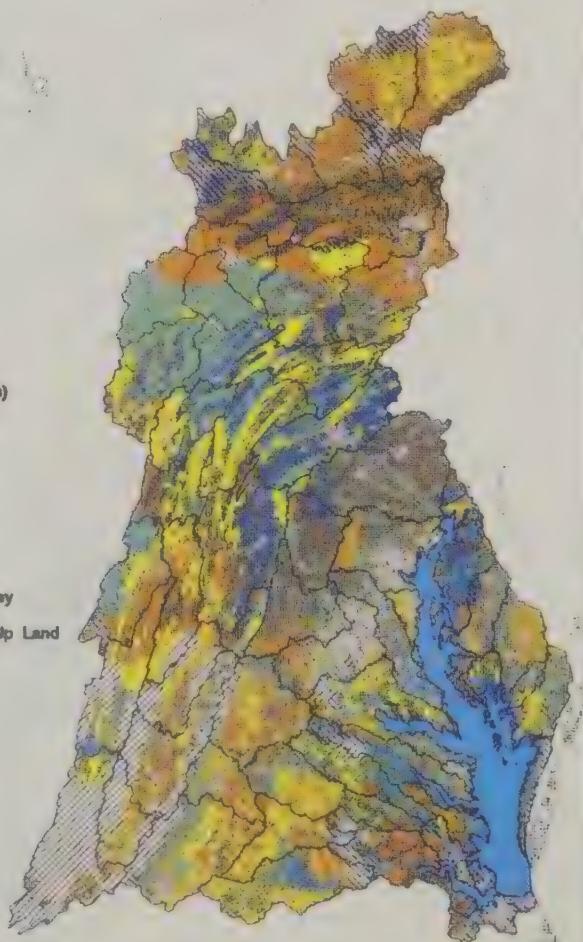
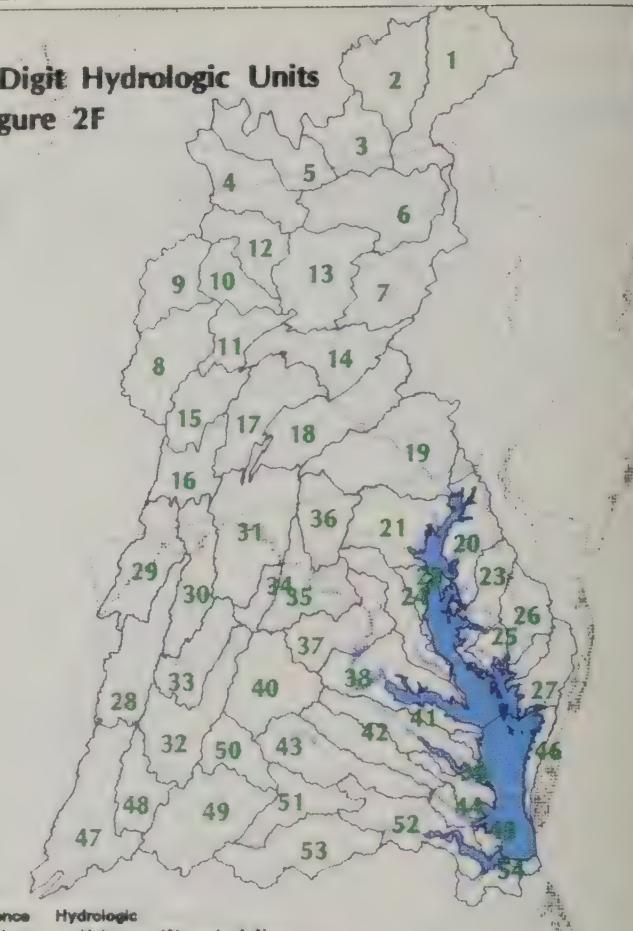
**Figure 2B**



**EI**

**Figure 2C**



**USLE****Figure 2D****Q****Figure 2E****8-Digit Hydrologic Units****Figure 2F**

| Reference Number | Hydrologic Unit | Watershed Name                    |
|------------------|-----------------|-----------------------------------|
| 1                | 2060101         | UPPER SUSQUEHANNA                 |
| 2                | 2060102         | CHENANGO                          |
| 3                | 2060103         | OWEGO-WAPPASENING                 |
| 4                | 2060104         | TIOGA                             |
| 5                | 2060105         | CHEMUNG                           |
| 6                | 2060106         | UPPER SUSQUEHANNA-TUNKHANNOCK     |
| 7                | 2060107         | UPPER SUSQUEHANNA-LACKAWANNA      |
| 8                | 2060201         | UPPER WEST BRANCH SUSQUEHANNA     |
| 9                | 2060202         | SINNEMAHONING                     |
| 10               | 2060203         | MIDDLE WEST BRANCH SUSQUEHANNA    |
| 11               | 2060204         | BALD EAGLE                        |
| 12               | 2060205         | PINE                              |
| 13               | 2060206         | LOWER WEST BRANCH SUSQUEHANNA     |
| 14               | 2060301         | LOWER SUSQUEHANNA-PENNS           |
| 15               | 2060302         | UPPER JUNIATA                     |
| 16               | 2060303         | RAYSTOWN                          |
| 17               | 2060304         | LOWER JUNIATA                     |
| 18               | 2060305         | LOWER SUSQUEHANNA-SWATARA         |
| 19               | 2060306         | LOWER SUSQUEHANNA                 |
| 20               | 2060002         | CHESTER-SASSAFRAS                 |
| 21               | 2060003         | GUNPOWDER-PATAPSCO                |
| 22               | 2060004         | SEVERN                            |
| 23               | 2060005         | CHOPTANK                          |
| 24               | 2060006         | PATUXENT                          |
| 25               | 2060007         | BLACKWATER-WICOMICO               |
| 26               | 2060008         | NANTICOKE                         |
| 27               | 2060009         | POCOMOKE                          |
| 28               | 2070001         | SOUTH BRANCH POTOMAC              |
| 29               | 2070002         | NORTH BRANCH POTOMAC              |
| 30               | 2070003         | CACAPON-TOWN                      |
| 31               | 2070004         | CONOCOHEAGUE-OPEQUON              |
| 32               | 2070005         | SOUTH FORK SHENANDOAH             |
| 33               | 2070006         | NORTH FORK SHENANDOAH             |
| 34               | 2070007         | SHENANDOAH                        |
| 35               | 2070008         | MIDDLE POTOMAC-CATOCTIN           |
| 36               | 2070009         | MONOCACY                          |
| 37               | 2070010         | MIDDLE POTOMAC-ANACOSTIA-OCCOQUAN |
| 38               | 2070011         | LOWER POTOMAC                     |
| 39               | 2080102         | GREAT WICOMICO-PIANKATANK         |
| 40               | 2080103         | RAPIDAN-UPPER RAPPAHANNOCK        |
| 41               | 2080104         | LOWER RAPPAHANNOCK                |
| 42               | 2080105         | MATTAPONI                         |
| 43               | 2080106         | PAMUNKEY                          |
| 44               | 2080107         | YORK                              |
| 45               | 2080108         | LYNNHAVEN-POQUOSON                |
| 46               | 2080109         | WESTERN LOWER DELMARVA            |
| 47               | 2080201         | UPPER JAMES                       |
| 48               | 2080202         | MAURY                             |
| 49               | 2080203         | MIDDLE JAMES-BUFFALO              |
| 50               | 2080204         | RIVANNA                           |
| 51               | 2080205         | MIDDLE JAMES-WILLIS               |
| 52               | 2080206         | LOWER JAMES                       |
| 53               | 2080207         | APPOMATTOX                        |
| 54               | 2080208         | HAMPTON ROADS                     |

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urban lands are included, they induce runoff rates that fall within the highest category shown here (data not shown).

*Priority Ranking of Watersheds.* The basis for establishing priorities for targeting technology, expertise, funds and research may vary for resource managers depending on programs and available resources. Total acreage of cropland in a watershed that is affected in a watershed is worth knowing. The proportion of non-urban, non-federal land that meets a criteria may be of interest. Also, the proportion of cropland regardless of acreage amounts may be useful. Three methods of expressing these factors and for establishing High, Medium and Low categories for priority ranking of groups of watersheds are described in "Methodology". A summary of these rankings is shown in the matrix, Figure 3. The number following each index refers to the calculation methods used (1, 2 and 3, respectively as described in "Methodology").

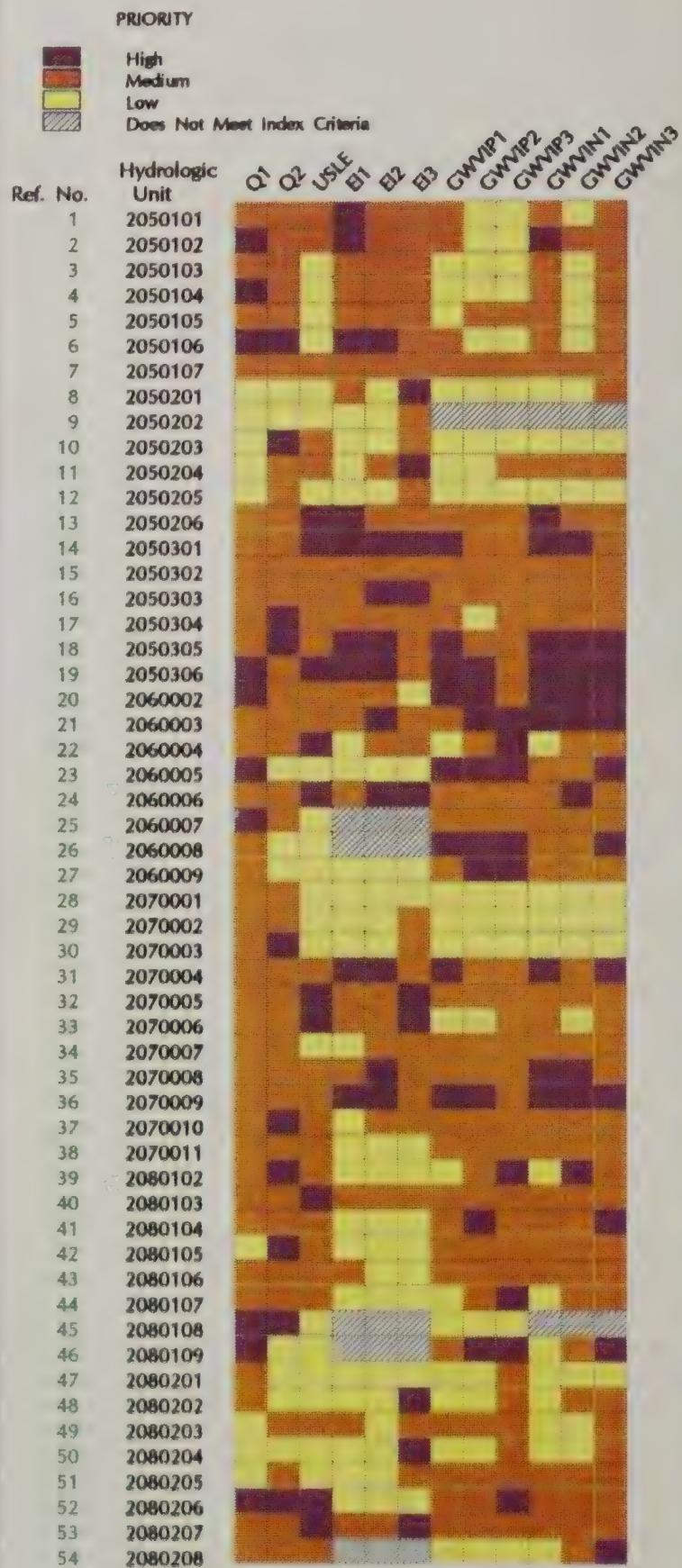
By nearly any method used, the Lower Susquehanna-Swatara (02050305) and the Lower Susquehanna (02050306) -- which are adjacent to each other (see Figure 2F) -- rank in the High category for every index. The Nanticoke (02060008) and the Pocomoke (02060009) -- also adjacent to each other in the Delmarva peninsula in Maryland -- rank high for pesticide leaching potentials. Also in Maryland, the Middle Potomac-Catoctin (02070008) and the Monocacy (02070009) qualify as High in EI, GVVIP and GWVIN. Certain subwatersheds in the Susquehanna drainage (the Upper West Branch, Sinnemahoning, Bald Eagle and Pine (02050201, 02050202, 02050204 and 02050205, respectively) generally show few potentials

for concern under the indices developed so far.

*The Potential for Impacts Upon Associated Resources.* The NRI contains a useful set of data describing the proximity of NRI sample points to specific land uses including cropped areas, forest lands, surface water and predominantly grassy areas. The 1982 NRI included wetlands. Though these relationships are not defined as up- or down-hill, these kind of data can begin to assist the resource manager in ecosystem-based planning by sub-categorizing the index potentials by the kind of most immediate resources likely to be affected. An example is shown in Figure 4. Figure 4A shows the percentage of cropland that has a potential for pesticide leaching to occur within 0.25 miles of wetlands. Of the 4.55 million acres of cropland in the watershed with a potential for pesticide leaching, 2.26 million acres (or 62% of the latter acreage) are within 0.25 miles of wetlands. This cropland is primarily located on the Delmarva peninsula in Maryland. Sixty-two percent, or 2.85 million acres are associated with water resources, Figure 4B. This is found primarily in the central and lower Susquehanna River basin and in the central Delmarva. Small areas near water resources are found in the lower Rappahannock River basin and in the upper reaches of the James River in Virginia. Of course many sample points are near both wetlands and water resources -- particularly in the Delmarva.

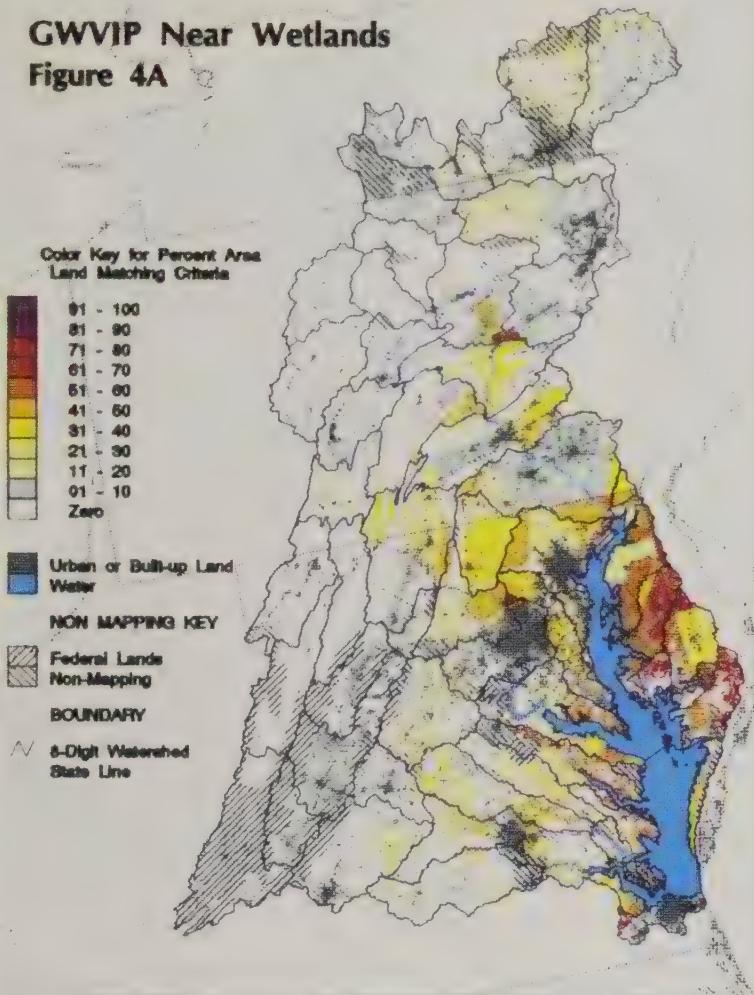
*Looking Closer at Environmentally Sensitive Regions in the Chesapeake.* The NRI-based indices are particularly useful in association with other spatial data bases to characterize ecologically important land units and their relationship to farming

**Figure 3. Matrix of Watershed Priority Ranks**



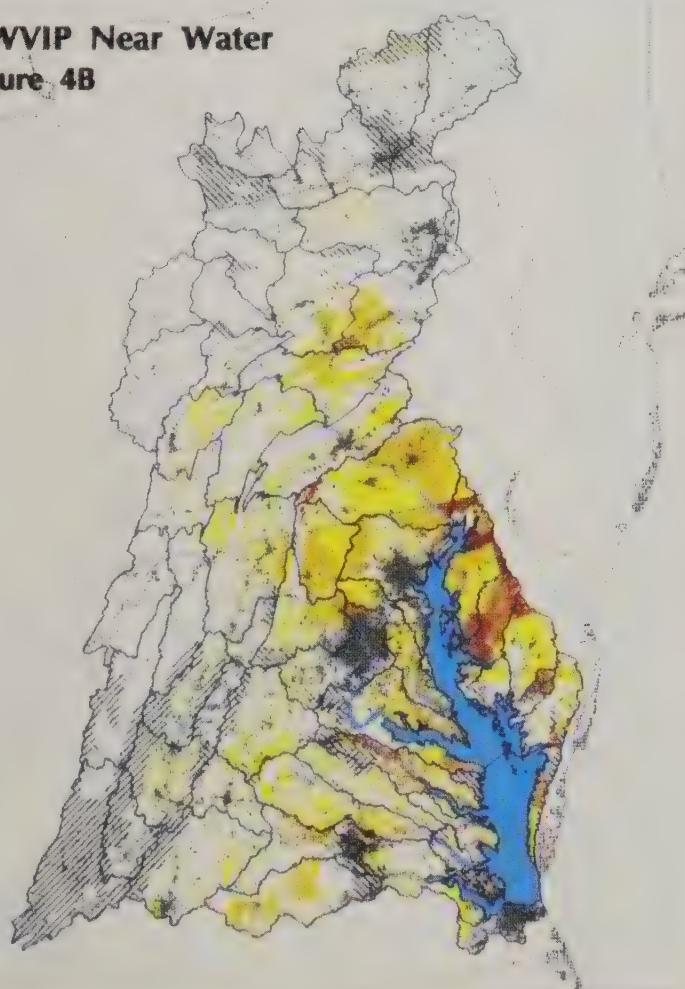
## GWVIP Near Wetlands

Figure 4A



## GWVIP Near Water

Figure 4B



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activities. For example, soils with a high percentage of Hydrologic Group A or highly permeable soils, defines an environmentally sensitive area with high potentials for many kinds of farm and nonfarm activities to affect ground water. Figure 5A shows that there are two major (potentially recharge) areas within the Chesapeake drainage that contain more than 66% soils that are in Hydrologic Group A. One region is divided between the Monocacy-Potomac drainage and in the Susquehanna River drainage. The other is in the Nanticoke watershed (approximately 500,000 acres in area) in Maryland and Delaware.

Land use over the latter potential recharge area is mixed containing several small towns (Federalsburg in Maryland to the west, Seaford and Bethel-Laurel areas in Delaware to the east (white and light grey areas in maps), cropland (orange areas) and forests (green areas, Figure 5B) and forested wetlands and non-forested wetlands (light pink and dark pink, respectively, Figures 5B and C). Animal confinement facilities scattered amid cropland areas (mostly for poultry) are also visible in aerial photographs. Of the 500,000 acres of the Nanticoke, one-half, or approximately 250,000 acres are characterized as being highly permeable. This condition is compounded by the fact that this area is extremely flat and has seasonally high and ponded water tables (data not shown). The watershed is heavily populated with forested and non-forested wetlands according to the National Wetlands Inventory, as shown in Figure 5C.

Three NRI polygons comprise the majority of the Nanticoke watershed. The area-weighted GWVIP scores in the two

major NRI polygons which comprise the Nanticoke watershed are among the highest in the Chesapeake drainage (data not shown). These NRI polygons within the Nanticoke are delineated by a rectangular hatched area (western watershed) and a parallel hatched area (eastern watershed) (Figure 5D). Thus, with the aid of ancillary land cover and soils data within an NRI polygon, resource managers can isolate special areas for priority attention and identify associated land uses which may be affected.

Mitigation efforts for such environmental potentials may also be varied using this approach. Managers may wish to encourage adoption of IPM and other more rigorous technologies in the mostly highly permeable soils of the watershed since few management options can mitigate the potential for large leaching pesticides to leach through highly permeable soils (Goss, Don W., personal communication). Given the relationship of cropland in these areas to seasonally high water tables and ponded soils, mitigation measures will differ also from those chosen for the potentially high recharge area in the Monocacy region where these particular soils conditions are minimal. Of great interest is the high rate of animal waste loadings (Chesapeake Bay Decision Support System Working Group, unpublished data) in the area that are known to contribute to the nutrient problem that exists in addition to pesticide leaching potentials in this area.

*Water Quality Benefits of a Conservation Program - the CRP.* The Chesapeake Bay was named a national priority watershed for implementation of conservation programs to mitigate impacts on water quality (Conservation Title XIV

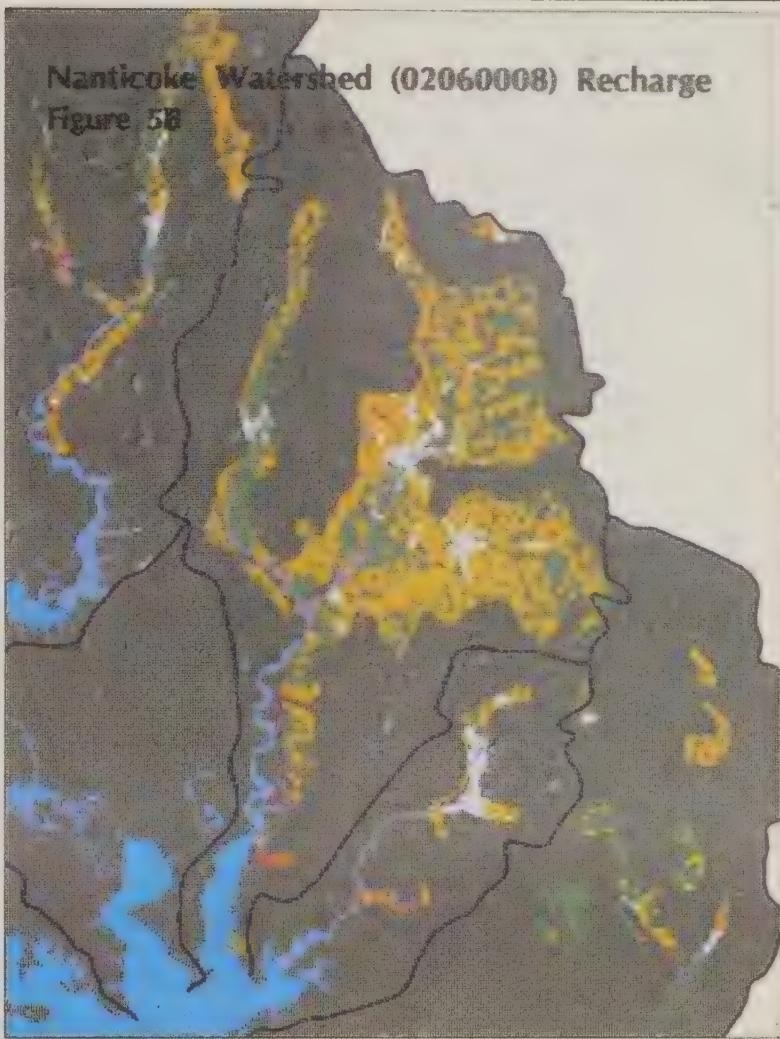
Potential Recharge Areas

Figure 5A



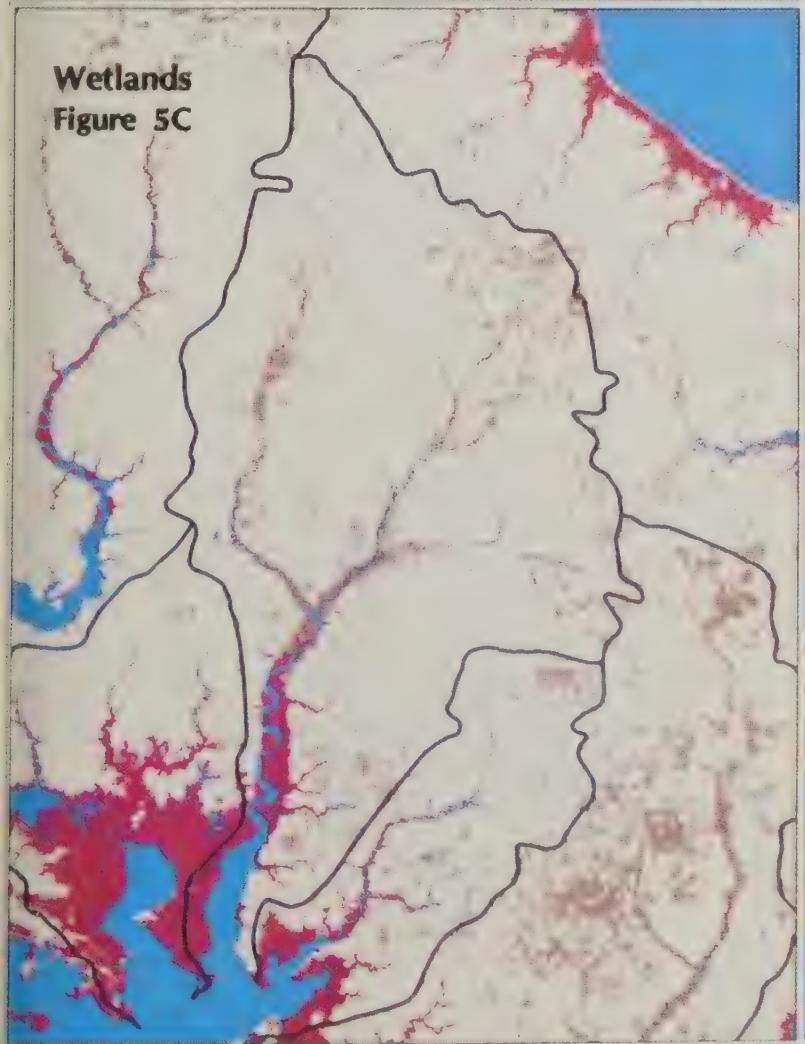
Nanticoke Watershed (02060008) Recharge

Figure 5B



Wetlands

Figure 5C



GWVIP

Figure 5D



on the 1990 Farm Bill). As requested by Congress the NRI has indeed been proven to be valuable when integrated with other data sets for estimating relationships between agricultural practices and water quality. An example of this in the Chesapeake watershed is shown in Figure 6. In all, some 4.0 million of the 8.18 million acres of cropland are eligible for enrollment in the CRP in the watershed. Sign-up rates have been very low, however, for many reasons and various means have been employed to encourage increased enrollments. Nevertheless, it is possible to illustrate ways in which the NRI can be used to assess the potential of a conservation policy to mitigate water quality (and other potential) impacts of farming.

The distribution of cropland acres eligible for the CRP is shown in Figure 6A. By the end of the 12th sign-up, approximately 130,000 acres were enrolled of which 92,000 acres had an  $EI > 8$  -- the rest of the acreage qualifying under low quality soils criteria, Figure 6B. Of the 130,000 acres enrolled, 88,000 acres were not only highly erodible, but also possessed a GWVIP greater than 124. 47,000 acres carried both GWVIP and GVVIN indices co-located at highly erodible cropland points. This illustrates one way through multiple indexing, potentials for water quality protection from multiple sources might be assessed. Many of these indices have been expanded by Ralph Heimlich, ERS/USDA (5).

## Conclusion

The great value of the NRI as an agricultural basis for ecological assessments has been only superficially explored in this report.

The current design of the CBDSS as built around varying information systems supports the goals and objectives of the proposed Chesapeake Bay Restoration Act of 1993. It allows the State Conservationists to:

- assess current and changing resource conditions of the ecosystem in a consistent manner that transcends jurisdictional boundaries
- focus program-based technology, personnel, research and funds on areas in the region with identified resource problems.
- assess program effectiveness and efficacy at regional and subregional levels in the watershed;
- link non-point source efforts with ecosystem-based assistance;
- assure integration of the CBDSS with existing information systems for optimal complementation, cooperation and collaborative implementation.

Indices have been built upon the NRI as supplemented from various data sources (National Wetlands Inventory, Land Use/Cover, STATSGO State Level Soils Data Bases) and given spatially more explicit addresses as described here. The NRI thus becomes useful in ecosystem- and watershed-based planning at regional levels.

Specifically, the State Conservationists can (1) assess effects of changing individual pesticides or groups of pesticides on the potential for ground water contamination. For example, for a given target pest such as broad leaf weeds on corn cropland and soils with a high potential to leach, they can select a lower-leaching pesticide; (2) change crops in

**CRP Eligible Cropland**  
**Figure 6A**

Color Key for Percent Area  
Land Matching Criteria

|    |      |
|----|------|
| 81 | 100  |
| 81 | 90   |
| 71 | 80   |
| 61 | 70   |
| 51 | 60   |
| 41 | 50   |
| 31 | 40   |
| 21 | 30   |
| 11 | 20   |
| 01 | 10   |
|    | Zero |

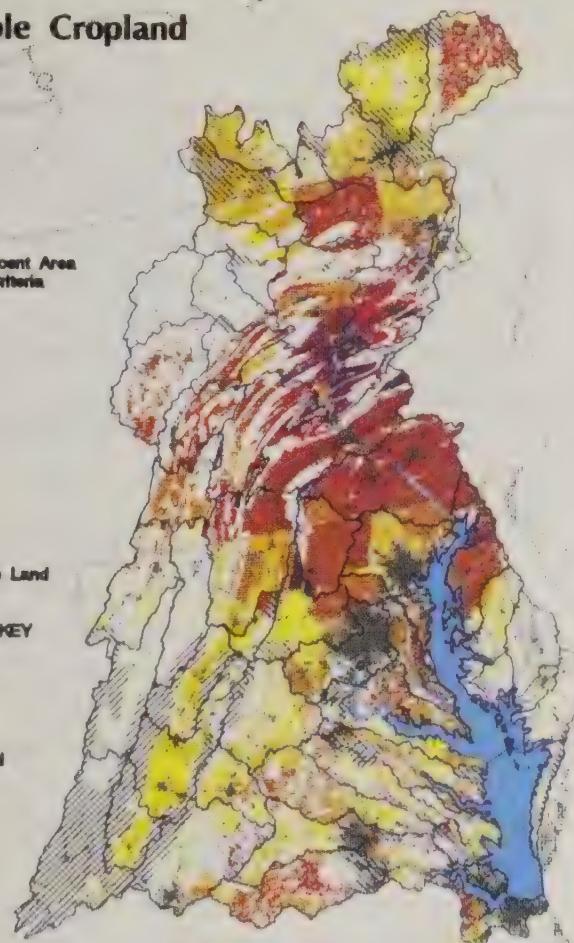
Urban or Built-up Land  
Water

**NON MAPPING KEY**

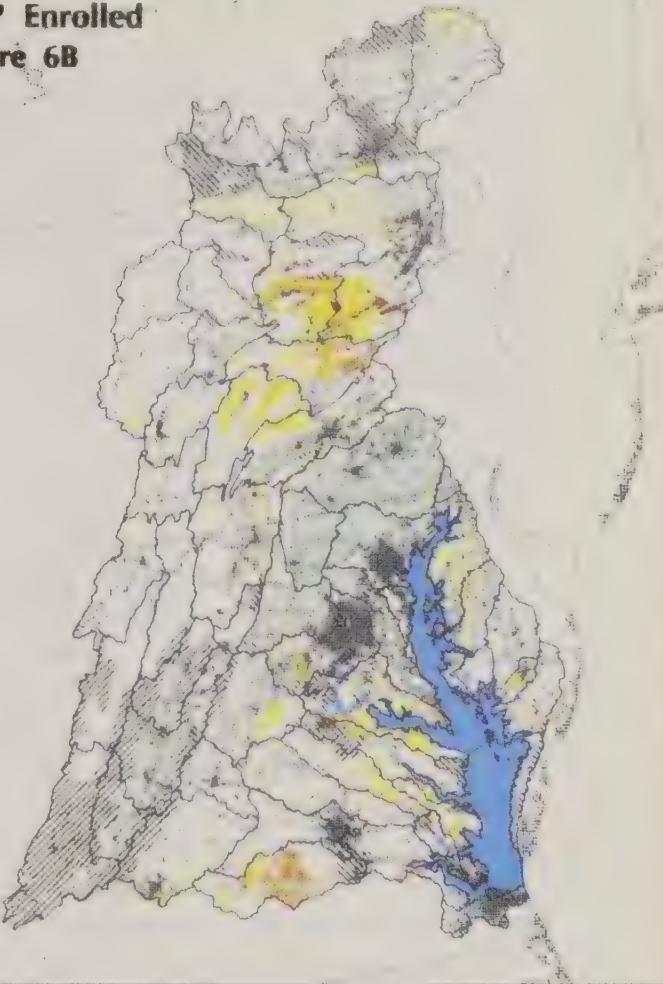
Federal Lands  
Non-Mapping

**BOUNDARY**

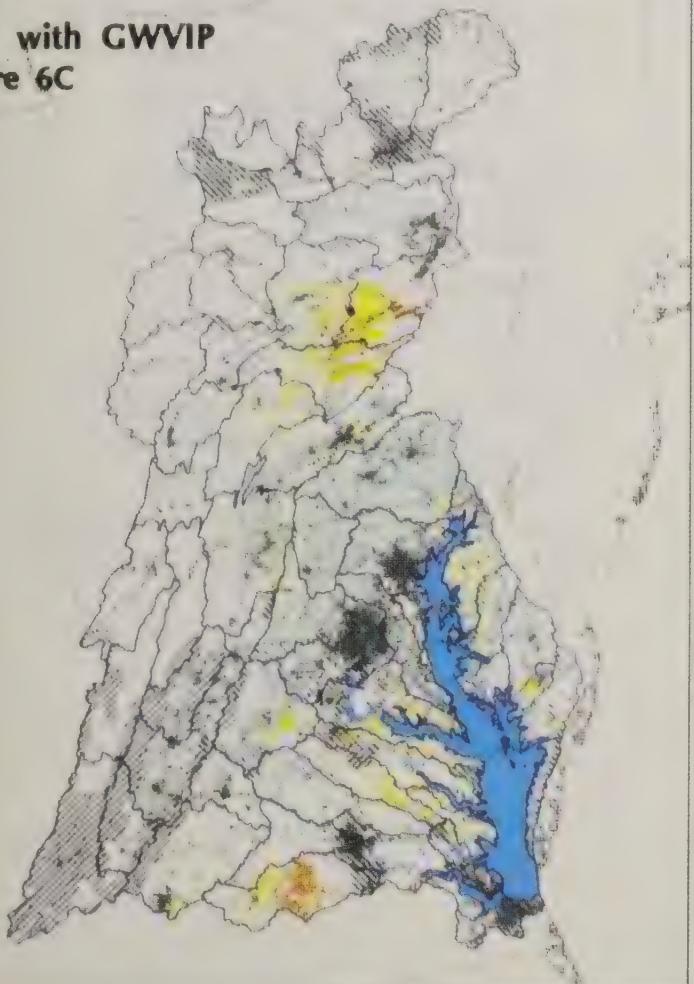
8-Digit Watershed  
State Line



**CRP Enrolled**  
**Figure 6B**



**CRP with GWVIP**  
**Figure 6C**



**CRP with Multiple Indices**  
**Figure 6D**



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order to change target pests and thus lower leaching pesticides in non-mitigatable conditions (all other factors being equal); (3) estimate the effects of activating potential cropland from intrinsic vulnerability of soils and the proposed cropping systems; and (4) screen new pesticides.

Now that a higher precision system is available, they can also begin to (1) estimate relational effects between croplands and sensitive resources such as waterbodies and wetlands. When river and waterbody reaches are integrated into the system for routing, they can (2) transport surface water impacts through intervening land cover types to downstream sites. They can now begin to (3) establish priority watersheds from individual indices and composite assessments and target technology, personnel, programs, information systems, funds and research to priority areas and ecosystems with these compound indices.

Enhancements currently being added to the system include (1) nutrient wastes from sixteen types of livestock (six species) by ZIP Code in the watershed, (2) a study to associate nutrients from septic fields with ground water and surface water, as well as the Bay, adds major contributions to an overall nutrient budget for the region that is currently under development, and (3) a pilot project to develop social and economic profiles of farm and nonfarm populations in the watershed in order to help identify ways to package conservation services to meet the needs of technology consumers in the region.

### Acknowledgements

The authors gratefully acknowledge the support of the NRCS/USDA Chesapeake

Bay Board of Directors, senior scientists at SCS National Headquarters and in particular, the insight and special encouragement of Mr. Richard Duncan, former State Conservationist for Pennsylvania, NRCS/USDA. We greatly appreciate the contributions of our colleagues and scientists in the Chesapeake Bay Decision Support System Working Group.

This project was funded in part by the Cooperative State Research Service of the U.S. Department of Agriculture through NCRI-Chesapeake, Inc. under agreement No 91-38813-6966. Any opinions, findings, conclusions or recommendations expressed are those of the authors and do not necessarily reflect the view of the U.S. Department of Agriculture.

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#### Footnotes

1. "Tools for Priority Ranking of 8-Digit Watersheds - an Interim Report Based on Five Agro-environmental Indices Developed for the Chesapeake Bay Decision Support System (CBDSS)" A Report prepared by the CBDSS working Group, January, 1995 as part of a Joint Project for the USDA/NRCS Chesapeake Bay Board of Directors. Available from NCRI-Chesapeake and working group members.
2. Factors related to management practices, including modes and timing of applications and conservation practices in crop production, are being built into a 'second tier' (National Agricultural Pesticide Risk Assessment - NAPRA) which also provides concentration and health advisory level data by NRCS/USDA (Plotkin et al, 1993). NAPRA is expected to be applied when it is available to the Chesapeake. Many other physical and chemical characteristics of both soils and pesticides affect interactions including temperature, moisture, microbial populations and other environmental conditions, but

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these are too specific and too regionally variable for inclusion in a first, or second tier assessment.

3. For GWIN, all crops with an index greater than 0 were considered to qualify whereas with the GWVIP, only those NRI points with an index greater than 124 qualified.

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# Using the National Resources Inventory in wildlife assessment models

By Steve J. Brady and Curtis H. Flather

National and regional wildlife assessments have been limited by the lack of geographically extensive data for both land base characteristics and wildlife populations. Only recently have data sets provided the standardization and geographic coverage needed to evaluate program alternatives over a scale consistent with program formulation. One such data set is the National Resources Inventory (NRI) which was authorized over 20 years ago with passage of the Rural Development Act of 1972 and the Soil and Water Resources Conservation Act (RCA) of 1977. This legislation mandated a periodic inventory of land use and land cover on nonfederal lands. Although the early focus of the NRI was on estimating and monitoring soil loss rates, the NRI has evolved into an inventory with multiple resource implications that include wildlife habitat. This evolution notwithstanding, the NRI has received limited use in evaluating how land use and land management on nonfederal lands affects natural resources that are products of the land base. In this paper we demonstrate the use of the NRI in addressing questions of land use impacts on wildlife resources over broad geographic regions. We review the results from two case studies--one which examines traditional game species management within a single state, the other which examines regional (multi-state) patterns of species diversity--and use these results to recommend improvements in the NRI.

## Case studies: species distribution and abundance associations with the NRI

A comprehensive evaluation of wildlife resource response to land management and

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land policy will require a mix of single-species and multiple-species approaches (27, 29). Habitat assessment methodologies have traditionally focused on developing single-species models for important game species, species threatened with extinction, or species thought to represent a group of species. These efforts will continue to make a valuable contribution; however, conserving biological diversity will require more emphasis on how wildlife communities respond to human-induced alterations of habitat. The case studies that we review exemplify each of these two broad approaches to wildlife assessment. In these case studies we use the term "model" to mean empirically generated statistical associations between attributes of wildlife resources (dependent variables) and habitat or land use (independent variables).

*Northern bobwhite and land use in Kansas.* Northern bobwhite (*Colinus virginianus*) populations have declined over the major portion of their range for more than two decades (3, 6) but no definitive explanations have been widely accepted. We were interested in determining if NRI data would be useful in relating regional patterns of bobwhite populations to agricultural land uses (see 2). To accomplish our objectives we correlated county-level agricultural statistics from the NRI and the Census of Agriculture (24) with surveys of bobwhite distribution and abundance.

Bobwhite population data for Kansas were available to us through both the Rural Mail Carrier Survey (RMCS, 26) and through the North American Breeding Bird Survey (BBS, 5). The RMCS data were available for all 105 counties in Kansas and were expressed as an index of

the number of bobwhite per 161 km of driving. Bobwhite were categorized in each county as: (1) present or absent, and (2) low-density ( $< 1.425/161$  km) or high-density ( $\geq 1.425/161$  km). BBS data were available for 36 routes occurring in 30 counties. We used the relative ranking of BBS routes by bobwhite abundance rather than the absolute values of population estimates (12) for the correlations.

While the NRI was implemented nationally to provide statistically reliable estimates of land cover and use at multi-county regions (i.e., Major Land Resource Areas), it was implemented more intensively in Kansas to provide county-level estimates. "County-level" NRI data were available for 47 counties in Kansas. NRI data were used to provide descriptions of the sequence of crops over time (crop rotations), soil characteristics, land cover, and distances between cover types (Table 1). Where appropriate all variables were converted to proportions to control for varying county sizes, while the soil related variables were weighted averages. Census of Agriculture data were also used to provide county estimates of crops and pesticide uses and were available for all counties in the state.

Statistical tests among discrete categories of bobwhite distribution (present/absent) and abundance (low/high) and land-use variables were conducted using the Multiple Response Permutation Procedure (MRPP, 19, 21). The null hypothesis was that land-use characteristics were identical among categories.

Statistical tests among continuous variables

**Table 1. County-level land use and soil variables from the National Resources Inventory that were associated with bobwhite distribution and relative abundance in Kansas.**

| Variable              | Description  |
|-----------------------|--|
| % LCC1                | % of county in Land Capability Class 1   |
| % LCC2                | % of county in Land Capability Class 2   |
| % LCC3                | % of county in Land Capability Class 3   |
| % LCC4                | % of county in Land Capability Class 4   |
| % LCC5                | % of county in Land Capability Class 5   |
| % prime farmland      | % of county in prime farmland soils  |
| % grazed              | % of county grazed by livestock  |
| % cropland            | % of county in agricultural crops  |
| % soybeans            | % of county in soybeans  |
| % wheat               | % of county in wheat   |
| % pasture             | % of county in pasture   |
| % woodland            | % of county in woodland  |
| % meadow              | % of county in hay   |
| % small water         | % of county occupied by small water bodies   |
| Distance to cropland  | Mean distance from randomly selected points to the nearest occurrence of cropland                            |
| Distance to grassland | Mean distance from randomly selected points to the nearest occurrence of grassland                           |
| Distance to water     | Mean distance from randomly selected points to the nearest occurrence of surface water                       |
| EI (water)            | Erodibility index based on the Universal Soil Loss Equation (28)   |
| EI (wind)             | Erodibility index based on the Wind Erosion Equation   |
| K factor              | Soil erodibility factor classified by soil characteristics   |
| R factor              | Rainfall and runoff factor, measure of the duration and intensity of rainfall                                |
| T factor              | Tolerable soil erosion rate that can occur without degrading the productive capacity of the soil             |
| Length of slope       | Length of the effective slope that water will run off as sheet flow before becoming concentrated flow        |
| % slope               | The vertical height (rise) of a hillside divided by the horizontal length (run), expressed as a percent      |
| LS factor             | Index that compares the soil loss from the field length and percent of slope to a standard unit (9%, 22.1 m) |

of bobwhite abundance with land use variables were conducted using Spearman's rank correlation test (4). The relationship of land-use variables to bobwhite abundance was determined with Least Absolute Deviation (LAD) regression (21).

Eight variables from the NRI were different ( $P < 0.05$ ) between counties where bobwhite were present as opposed to absent (Table 2). There were 16 NRI variables that differed ( $P < 0.05$ ) between low- and high-density counties (Table 2).

Seven NRI variables were common to both presence/absence and low/high tests. Within the range of counties where bobwhite were present there were 19 NRI variables highly correlated with bobwhite abundance (Table 3). Four NRI variables (percent small water bodies, percent woodland, percent soybeans, and mean distance to cropland) best explained the relationship (Agreement = 0.49,  $P < 0.0001$ ) between bobwhite abundance and land use patterns in the regression test.

**Table 2. Multiple Response Permutation Procedure results of Rural Mail Carrier Survey bobwhite distribution with county level National Resources Inventory data for counties where bobwhite were present ( $n = 36$ ) or absent ( $n = 11$ ), and for counties with high ( $n=18$ ) or low ( $n=18$ ) abundance.**

| National<br>Resources Inventor | Present/Absent<br><i>P</i> | High/Low<br><i>P</i> |
|--------------------------------|----------------------------|----------------------|
| % LCC1                         | 0.0831                     | 0.4971               |
| % LCC2                         | 0.2007                     | 0.0424               |
| % LCC3                         | 0.2656                     | 0.0108               |
| % LCC4                         | 0.3156                     | 0.0480               |
| % prime farmland               | 0.0001                     | 0.0315               |
| EI (water)                     | 0.0002                     | 0.0003               |
| EI (wind) <sup>a</sup>         | 0.0306                     | 0.4128               |
| % grazed                       | 0.1178                     | 0.0522               |
| % cropland                     | 0.0154                     | 0.0037               |
| % soybeans                     | 0.0783                     | 0.0030               |
| % wheat                        | 0.1015                     | 0.0239               |
| % pasture                      | 0.1532                     | 0.0246               |
| % woodland                     | 0.0107                     | 0.0001               |
| % meadow                       | 0.0001                     | 0.0001               |
| % small water                  | 0.0032                     | 0.0003               |
| Distance to cropland           | 0.8724                     | 0.0004               |
| Distance to grassland          | 0.0002                     | 0.0130               |
| Distance to water              | 0.0750                     | 0.0023               |

<sup>a</sup>EI (wind) was only calculated only for  $n = 23$  counties where bobwhite were present and  $n = 11$  counties where bobwhite were absent.

**Table 3.** Spearman's rank correlation coefficients and probabilities of 1982 Rural Mail Carrier Survey data for bobwhite abundance with county level National Resources Inventory data for counties where bobwhite were present ( $n = 36$ ).

| Variable               | $r_s$  | $P <$  | Variable              | $r_s$  | $P <$  |
|------------------------|--------|--------|-----------------------|--------|--------|
| R factor               | 0.806  | 0.0001 | Distance to cropland  | 0.543  | 0.0006 |
| EI (wind) <sup>a</sup> | -0.760 | 0.0001 | % cropland            | -0.524 | 0.0010 |
| % woodland             | 0.739  | 0.0001 | Distance to grassland | -0.426 | 0.0096 |
| % small water          | 0.701  | 0.0001 | % LCC4                | -0.407 | 0.0136 |
| T factor               | -0.696 | 0.0001 | % wheat               | -0.404 | 0.0146 |
| % pasture              | 0.633  | 0.0001 | % LCC3                | 0.388  | 0.0193 |
| EI (water)             | 0.618  | 0.0001 | % LCC5                | 0.356  | 0.0333 |
| K factor               | 0.600  | 0.0001 | % grazed              | 0.356  | 0.0333 |
| % meadow               | 0.597  | 0.0001 | Length of slope       | -0.201 | 0.0574 |
| % soybeans             | 0.560  | 0.0004 | LS factor             | 0.185  | 0.0805 |
| Distance to water      | -0.547 | 0.0006 | % slope               | 0.181  | 0.0885 |

<sup>a</sup>EI (wind) was calculated only for  $n = 23$  counties.

*Land use intensity and patterns of avian diversity.* Given the variety and sheer number of species that could inhabit a defined area, conserving each of these species by addressing life history requirements individually is infeasible (7, 8). Conservation goals directed at maintaining or improving biological diversity are forcing wildlife stewards to consider levels of biological organization above the species (e.g., measures of wildlife community structure) in evaluating the relative merits of alternative land management policies (13, 20).

Flather et al. (10) completed an analysis of land use factors potentially affecting avian community structure. The modeling approach is based on the observation that vertically complex habitats tend to support more species than simple habitats (1, 16). A vertical habitat structure index (VHSI) was quantified using the 1982 NRI (23) as a ratio of the number of habitat strata

observed at an inventory point and the number of strata expected under the potential natural vegetation as defined by Kuchler (15). The index tended to vary between 0 (indicating highly disturbed, vertically simple habitats) and 1.0 (indicating undisturbed habitats with vertical habitat structure equal to that expected under natural vegetation).

Two measures of avian community structure were used to test the hypothesis that greater vertical habitat complexity was associated with a more diverse bird community. The test was restricted to eastern forest ecosystems and both measures were derived from the BBS. First, a measure of faunal integrity was estimated as the proportion of the expected bird species that were observed by the BBS. The list of expected bird species was determined from a continental range-map study (14). A second measure of avian community structure quantified the

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dominance pattern among species. An index proposed by McNaughton (18) estimates dominance as the proportion of the total number of individuals observed that is restricted to the two most abundant species. These indices of community structure were chosen to capture two aspects of diversity change under land use intensification--a reduction in species number and the tendency for disturbed communities to be dominated by a few, very abundant, generalist species.

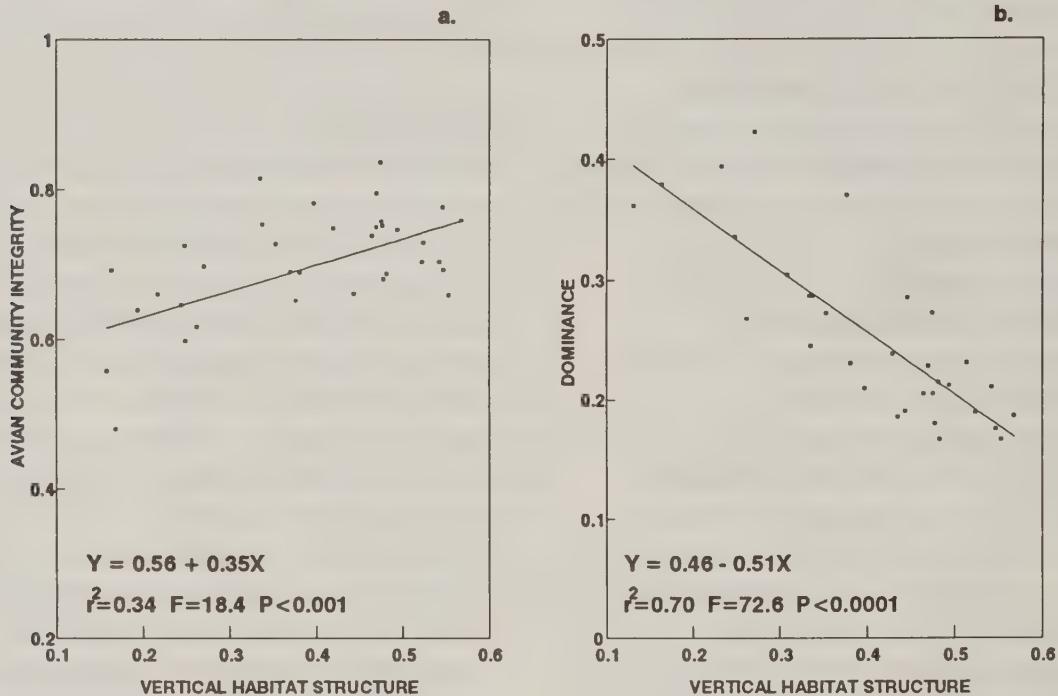
Estimates of vertical habitat complexity and bird community structure were estimated for landscape-scale geographic units defined by Major Land Resource Areas (22). Vertical habitat structure was related to avian community structure in a manner consistent with the hypothesis of greater diversity in less disturbed environments (Figure 1). The strength of the association between vertical habitat structure and bird community structure was dependent upon the diversity measure. Although both indices of bird diversity were statistically significant, simple linear regression analysis indicated that only 34% of the total variation in avian community integrity was explained by vertical habitat structure. The magnitude of the unexplained variation in bird community measures was not unexpected. The arrangement of land types (i.e., the size, shape, and dispersion of habitat) has been found to also affect the distribution and abundance of species within a region (10). Additional variables were then calculated from the NRI data including the number of land types within 402 m of an inventory point (computed from the "distance to land cover type" elements), percent urban and built-up land, and the variance of the VHSI. These additional NRI variables

moderately improved the model ( $R^2 = 0.50$ ,  $F = 7.88$ ,  $P < 0.0001$ ). We then used the USGS digitized land use and land cover spatial data (25) to compute a suite of more comprehensive landscape structure variables that were allowed to compete with the NRI variables in a stepwise-selection regression model. The fully specified model retained three NRI variables (VHSI, percent urban and built-up, and the number of land types within 402 m) but also selected two USGS spatial variables (land type dominance, and the perimeter/area fractal measure of forest edge complexity). This model accounted for 63% of the variation in avian community integrity.

The relation between vertical habitat complexity and avian dominance differed from that observed with community integrity. Much of the variation in avian dominance was explained by vertical habitat complexity ( $r^2 = 0.70$ , Figure 1b). This indicates that different measures of avian communities are likely to respond differently to land use and land cover patterns and that multiple measures of wildlife community structure should be examined in assessing impacts from land intensification.

#### **Recommendations: enhancing the capability of the NRI to assess wildlife**

Experience with the NRI data leads us to conclude that its multiresource composition and capability to assess land based trends over the decade back to 1982 make it an extremely rich data source. The full potential of the NRI will only be realized as analysts use their creative skills to elucidate the intricacies of the multiresource interactions as yet untapped within the database. There are, however,



**Figure 1.** Relations between vertical habitat structure and avian community integrity (a) and dominance (b).

three recommendations that we offer that could improve NRI-based assessments of ecological relationships.

First we recommend expanding the data collection effort to include all federal lands. Our case studies were restricted to those regions of the U.S. where federal lands comprise a small proportion of the land base. Much of the western third of the U.S. is federally owned making it difficult to associate NRI land-based patterns with wildlife distribution and

abundance, water, or other resources that are independent of land ownership boundaries.

Secondly, we recommend digitizing land cover on the Primary Sample Units. The influence that the spatial configuration of habitat has on the distribution and abundance of species has a long history of ecological investigation. Island biogeographic theory (17) generated extensive inquiry into how the size and arrangement of island habitats affect

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species composition. These concepts have now been extended under a landscape ecologic perspective (see 11) where the focus is on the spatial structure of habitat patches and the inter-patch land use matrix (9). Patch size, connectivity, and fragmentation could be quantified and other fine scale elements could be identified including the presence of odd habitat areas and riparian green belts, etc. if PSU cover was digitized. Simple estimates of land composition (i.e., amounts of land in various uses) are inadequate to model how wildlife resources may respond under different land policy scenarios as demonstrated in our example using the VHSI and the index of avian community integrity.

Finally, our case studies were restricted to avian taxa. There is no nationally standardized inventory of biological organisms that corresponds to the sampling intensity and design of the NRI. A coordinated and comprehensive inventory of biological resources with the land-based NRI data would be very helpful in associating land use alternatives with biological responses. Evaluating land management impacts across a diverse set of taxa would greatly improve our capability to assess ecosystem health.

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# **Regional Agroecosystems Characterization Using the National Resources Inventory**

**By Michael R. Burkart, Mason J.  
Hewitt, S.L. Oberle, and D.E.  
James**

## **Abstract**

An agroecological framework is used to examine the relations among natural resources and agriculture. Spatial representation of selected agroecosystems characteristics was accomplished using the National Resources Inventory (NRI). Natural resource and anthropogenic variables from the NRI were spatially aggregated to produce maps showing the regional variability in area-weighted values of agroecosystem components. Maps of natural vegetation, agricultural land use, crop diversity, artificial drainage, irrigation, net soil loss, and conservation practices show the extent to which resources have been modified to support agriculture in the midwest. Examination of these and other elements in an agroecosystem framework may be useful in the search for systems to sustain agriculture and natural resources in the region. Such a framework can also be used to locate areas where mitigation of degraded resources is most needed; identify areas where research into causes of degradation can yield the most information; and where policies to improve off-site damage may be most effectively implemented.

## **Introduction**

The purpose of this paper is to demonstrate how the National Resources Inventory (NRI) can be interpreted to characterize agroecosystems. The need for such a characterization grew out of the attempts to define how local-scale research can be applied to regional-scale issues of the impacts of agricultural management systems on water quality (12, 13). Agroecosystems have displaced natural biological communities especially in the

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most agriculturally productive regions of the Nation. The 12-state area comprising the midwest U.S. is one of the most agriculturally productive regions where intense agricultural production has been possible because of the quality and availability of natural resources and suitable topography. One requirement of this intense agriculture is the cumulative application of 60% of the Nation's nitrogen fertilizer (18) and pesticides (3) in the region.

Agroecosystems are intentionally disturbed ecosystems that, through agricultural activities, are being forced into states different than the natural, unmanaged systems from which they are derived (2). These systems continue adapting to modifications imposed by agriculture often resulting in negative natural resource responses, the scale of which is only recently being adequately measured.

Techniques for aggregation, analysis, and display of characteristics are presented using a geographic information system (GIS). In a GIS, characteristics and combinations of factors can be spatially delineated and related to define agroecosystems from a variety of perspectives. The geographic reference of the NRI provides an opportunity to view environmental concerns such as soil and water degradation. The digital locations of NRI sampling points will greatly expand this and other analytical opportunities. Our GIS representation of an agroecological framework is initially applied to the midwest region, but is readily applicable to a national scale, particularly with the NRI as a foundation. Consequently, the framework presented here has the potential to support the extension and application of

research resulting from these efforts as well as define areas where additional research may be most effectively established.

## Data and Methods

### *National Resources Inventory*

The 1982 NRI data were used as an experimental data set because this was the most extensive of the two inventories available when this research began. A provisional data set from the 1982 inventory for the region of interest was made available by SCS to experiment with methods for interpreting the data. One NRI variable critical to spatial analysis is the expansion factor. This variable is the area represented by each point. With this value, the data at each point can be weighted to extend the information beyond the measurement point.

The NRI data can be spatially aggregated, displayed, and analyzed in polygons. The data points in the provisional data set are geographically referenced using three parameters; major land resource area, county, and hydrologic unit. Digital locations of these polygon coverages from other sources can be intersected resulting in 7,378 polygons of various sizes in the 12-state midwest. A similar technique for displaying these data was used by Kellogg et al. (6).

The release of the 1992 NRI timed for this conference will add a temporal dimension to the spatial analytical potential of each inventory. The final step needed to improve the spatial analysis is the digital geographic reference of NRI sample points. With digital locations, NRI points or clusters of points can be directly related to other geographically referenced data such as near-surface aquifers, streams and

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other water bodies. The geographic link among such data with greatly enhance the application of NRI variables in simulations of agricultural impacts on water and other environmental resources

### *Geographic Analysis*

Two types of data aggregation in the geographically referenced polygons were used to display the regional distribution of individual and combinations of NRI variables; representative values and frequency of occurrence. For both types of aggregation, the variable value was weighted by the expansion factor providing the area represented by the sample point.

Representative value maps of variables were generated by multiplying the variable by the expansion factor, summing the products in each polygon and dividing by the total expansion factor in each polygon. Representative value maps show the area weighted spatial distribution of continuous variables.

Frequency maps were produced by summing the expansion factors for points meeting the map criteria; dividing by the total of all expansion factors in each polygon; and multiplying by 100 to obtain a frequency in percent. Frequency maps are used to show the spatial distribution of area weighted values of variables with specific classes of values rather than continuous values. Class variables include such items as crop type with many potential values and variables such as wetland with a value of only presence or absence.

### **Midwest Agroecosystems Characteristics**

The framework for agroecosystem characterization is based on combining information on the natural resources and

anthropogenic activities of the region. Natural resource factors represent features of ecosystems including soil characteristics, hydrology, climate, and natural vegetation assemblages.

Anthropogenic factors are those introduced by humans exclusively for agricultural production. These include management practices such as crop selection, irrigation, and tillage, but also more permanent landscape modifications such as surface and subsurface drainage systems, terraces, and windbreaks.

Within this framework, seven maps were prepared to demonstrate how the NRI data can be analyzed to show the spatial variability of natural resource characteristics and regional extent of anthropogenic impacts. With a combination of maps such as these, other analyses of the NRI, and similar regionally consistent data, it will be possible to better understand the collective impact of existing agricultural systems on natural resource. A characterization framework is necessary to evaluate policy options which could affect the form and distribution of agricultural systems. James and Hewitt (4) explored the utility of such a framework using an environmental impact model to support silvicultural policy decisions.

### *Residual Natural Vegetation*

The highly productive agriculture of the Midwest was established through modification of the landscape to use the natural resources of the region. These modifications include permanent changes in the composition and structure of resources. Other more extensive changes have also been made in the form of annual stresses applied to soil, water, and

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vegetation to promote the production of a limited number of plant and animal species in many areas.

Natural vegetation assemblages have been mostly removed in the heart of the region to accommodate intensive row crop agriculture. Four natural vegetation assemblages are recorded in the NRI; wetland systems, riparian vegetation, forests, and rangeland. These are remnants of natural assemblages although they may not adequately represent the virgin or complete systems from which they were modified. The frequency of occurrence of one or more of these assemblages was mapped to show areas with residual natural vegetation (Fig. 1). The lack of abundant natural vegetation, except on the periphery of the region, demonstrates the degree to which biological diversity has been reduced in the region. Natural vegetation assemblages occur on less than 13% of the land surface in the most intensively cropped areas of the region.

Detailed data are available in the NRI which describe some native plant communities for those areas where natural vegetation exists. It may be possible to use these data to develop landscape management strategies for protecting and improving environmental quality without reducing the areas of intensive agricultural production. Particularly interesting is the potential for strategic inclusion of wetlands and natural riparian buffers as a means of mitigating export of excess nutrients and pesticides to water resources suggested by the National Research Council (9).

#### *Cropland and Pasture*

Agricultural land use is so dominant in the region that exclusion of agriculture

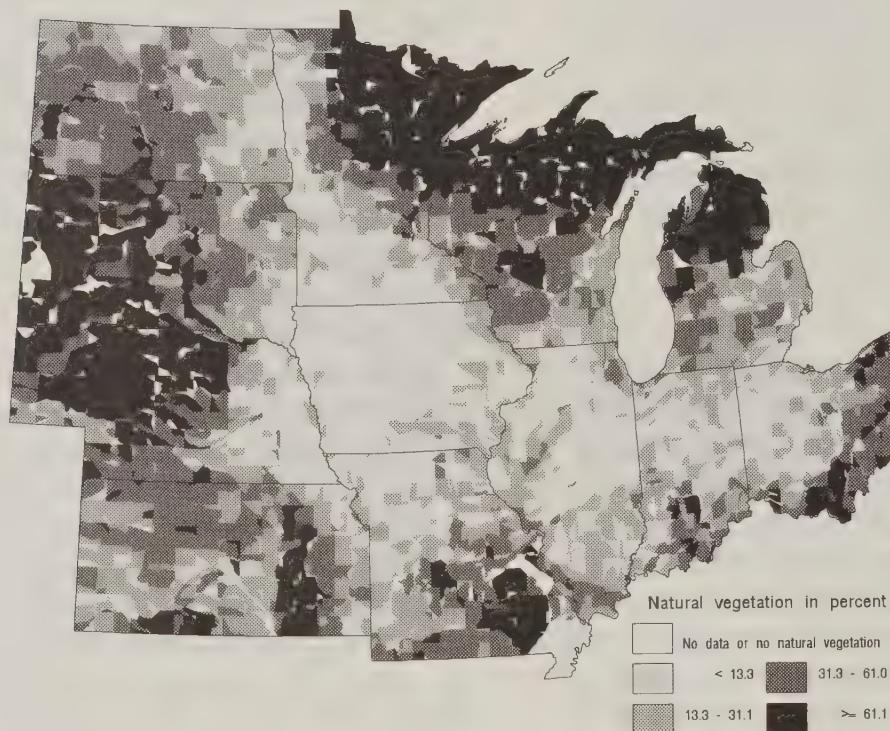
from an ecosystem definition would eliminate most of the land surface from consideration. This is readily illustrated by mapping the frequency of land used for agricultural production. Cropland and pasture were selected from the NRI to represent the extent of agricultural land use (Fig. 2). The frequency of land used for crops and pasture is more than 50% in most areas of the region. Greater than 90% of the land is used for agriculture in the most intensively cropped areas of the region (Fig. 2).

#### *Crop Diversity*

In agroecosystems, the dominantspecies are artificially selected and frequently restricted to one or two species. Increasing plant diversity within agroecosystems may be essential for ensuring ecological stability and long-term economic viability. Crop diversity in the region was mapped using cropping data for 1979 to 1982 (Fig. 3). Individual records were selected where the four-year crop sequence included four different species. Although this is perhaps an unorthodox measure of plant diversity, it is an attempt to account for diversity in the principal plant communities of the region. With this definition of crop diversity, most of the region has less than 6% of the land used for multiple crops (Fig. 3). The most common crop sequence is corn and soybeans (data not shown), but this sequence was not included in the map unless it included at least two additional species in the four-year history. Other areas with smaller fractions of land with multiple crops include non-crop areas (Fig. 1 and 2) and long-term monocultures such as wheat *Triticum aestivum* L.) and corn in the irrigated west (data not shown).

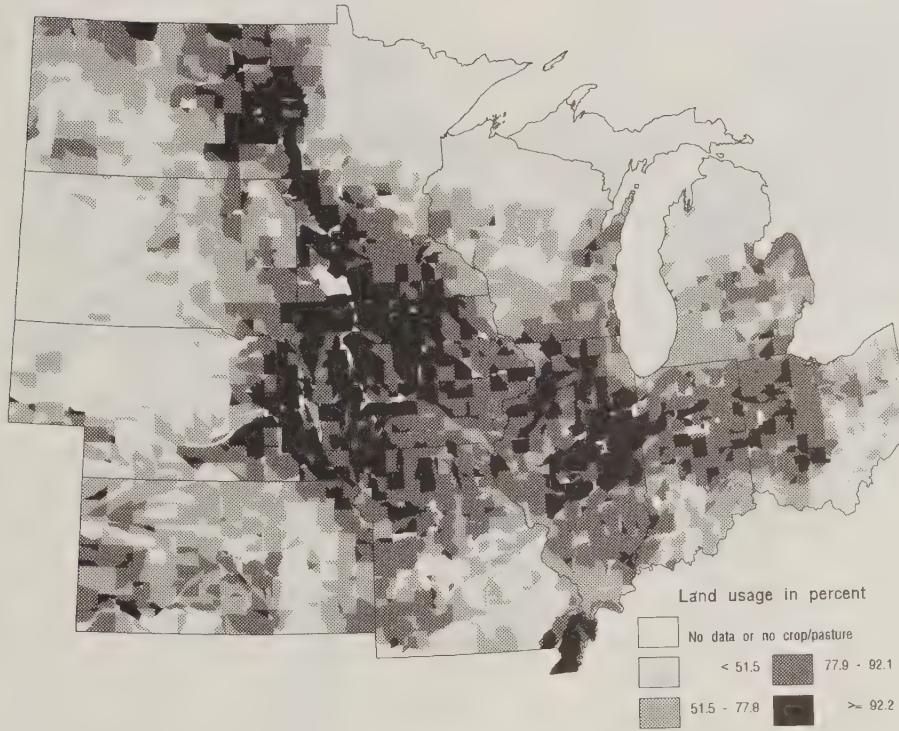
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**Figure 1. Natural Vegetation in percent**



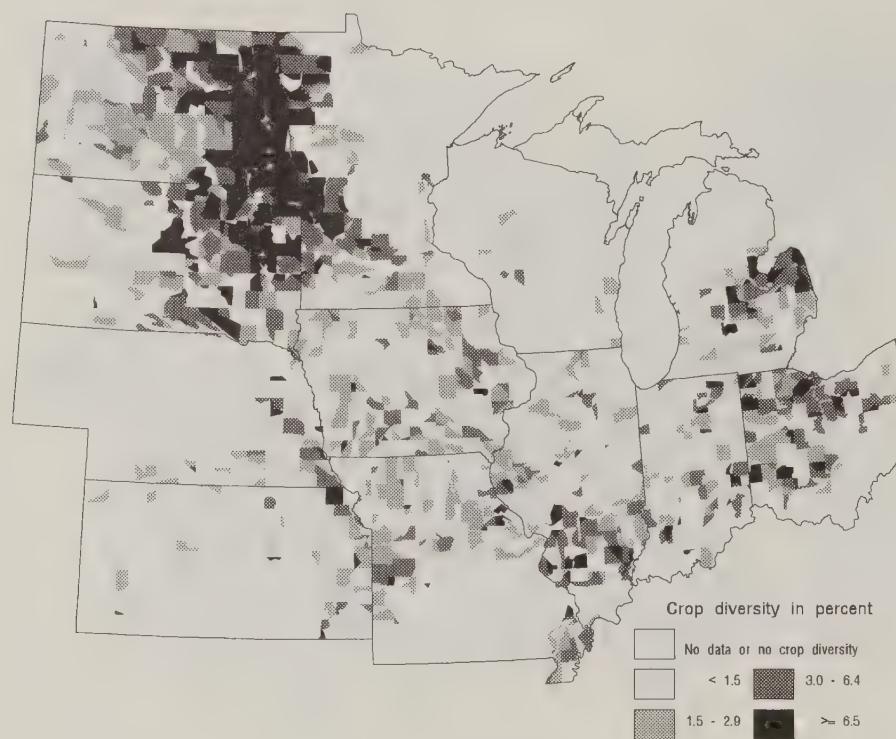
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**Figure 2. Land usage in percent**



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**Figure 3. Crop diversity in percent**



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Since most of the cropland of the region produces fewer than four crops (Fig. 3), a significant potential exists for greater biodiversity. Use of crop rotations including cereals and legumes can enhance biodiversity and at the same time reduce the need for external nitrogen fertilizer inputs and can interrupt plant and insect pest cycles, thus reducing the need for chemical controls. Use of soil conserving crop rotations, including cover crops, in conjunction with alternative cropping patterns such as intercropping, contour strip cropping, and relay cropping also provides opportunities to enhance crop diversity.

#### *Hydrologic and Edaphic Characteristics*

Consistent annual crop production in many parts of the region is only possible after substantial manipulation and exploitation of soil and water resources. Permanent drainage of the landscape has been an effective tool to expand the amount of land that can be cultivated or to improve the efficiency and timing of specific farming practices. For example, drainage has eliminated as much as 90% of the wetlands in Iowa and continuing drainage projects will add to the loss of 60% of the wetlands in North Dakota (16). Three types of artificial drainage practices are recorded in the NRI: subsurface drainage, field ditch surface drainage, and main or lateral surface drainage. Sample points were selected which had one or more of these practices and a frequency map (Fig. 4) illustrates the distribution of land to which artificial drainage has been applied. The frequency of land with artificial drainage is greater than 35% in some areas of the region with the most

intensive crop and pasture production (Fig. 2 and 4).

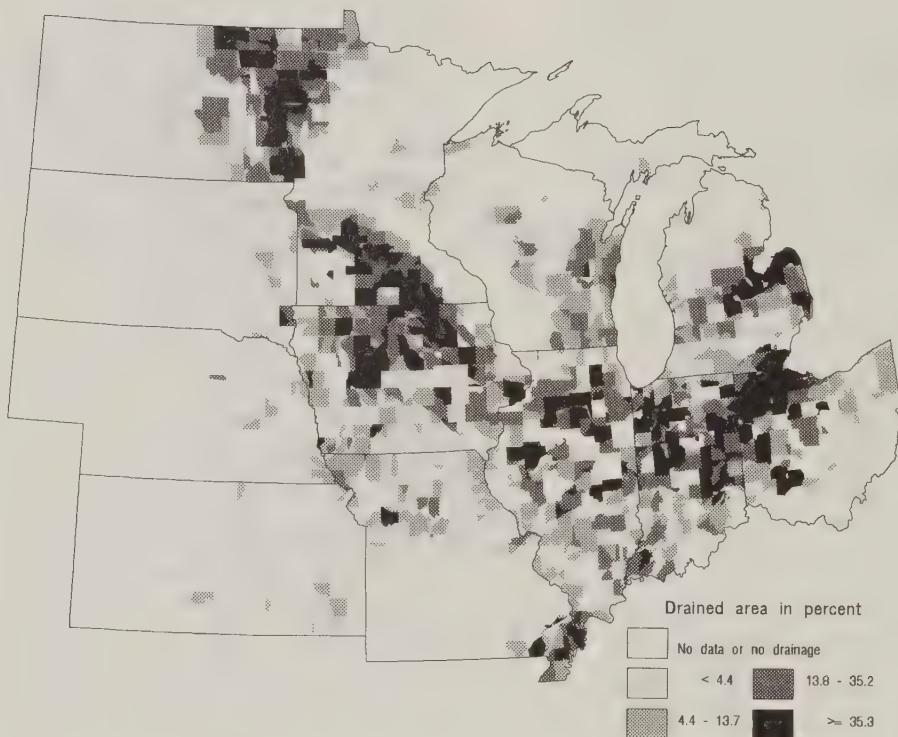
Two important changes to the environment directly result from artificial drainage; loss of wetland resources and associated local ecosystems, and accelerated flux of water to streams. The accelerated flux, particularly from subsurface drainage, reduces the residence time of agrichemicals in soils, thus increasing the potential for rapid transport of contaminants to larger surface water resources.

Although irrigation is not required for agricultural production in most of the region, it is essential for maintaining crop productivity in the extreme west where annual precipitation deficits preclude cultivation of corn and other large water-demand crops. In some areas more than 22% of the land derives at least one-half of the water needed for crop production from irrigation (Fig. 5). The application of technology to exploit water resources in the western part of the region coincides with a marginal frequency of natural vegetation assemblages in these areas. In areas requiring irrigation, wetlands, forests, rangeland, and riparian areas generally cover less than 31% of the land area (Fig. 1). In these areas, the water to sustain these communities is diverted to support crops. This diversion also has potential negative impacts on valuable ground-water resources such as the high plains (Ogalalla) aquifer (7), diversion of stream flow, and loss of wetlands supported by shallow ground water.

Irrigation increases the potential for leaching agricultural chemicals into groundwater. A regional reconnaissance of the near-surface aquifers in the region (1) shows a substantially larger frequency

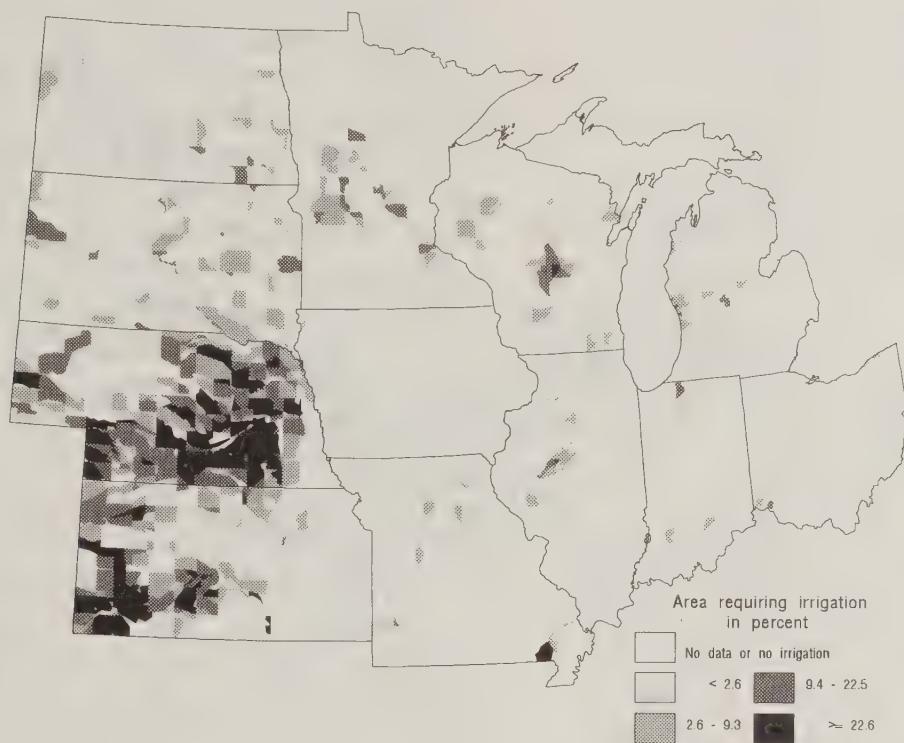
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**Figure 4. Drained area in percent**



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**Figure 5. Area requiring irrigation in percent**



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of contamination by nitrate and herbicides in irrigated areas when compared to other parts of the region.

Soil erosion by water has been a major concern among producers and policymakers for several decades. This concern has generated considerable investment in research and technology development directed at reducing erosion. The NRI contains a soil loss tolerance factor (TFACTOR) determined for each sampling point. Another NRI variable related to soil loss is the average annual soil movement due to sheet and rill erosion as estimated using the universal soil loss equation (USLE). Thus, subtracting the TFACTOR from USLE results in a measure of permanent soil loss.

A representative value map (Fig. 6) shows the distribution of net soil loss, illustrating the extent to which this critical resource is being lost. Net soil loss exceeds 2.6 t/ha/yr in the central part of the region. In some areas, net soil loss is greater than 5.5 t/ha/yr. The resource loss was estimated after including the effects of conservation practices designed to retain soil on the land. This variable is an estimate of erosion rates based on the response to long-term climatic conditions and the management practices used in 1982. If these annual soil losses were to occur over several decades, as is likely, it is easy to see why chemical and energy use must increase to maintain production in areas depleted of the resources critical to agriculture.

### *Resource Conservation*

Agricultural productivity gains since the 1950s have resulted from the development of production systems that rely heavily on auxiliary inputs of energy and chemicals to

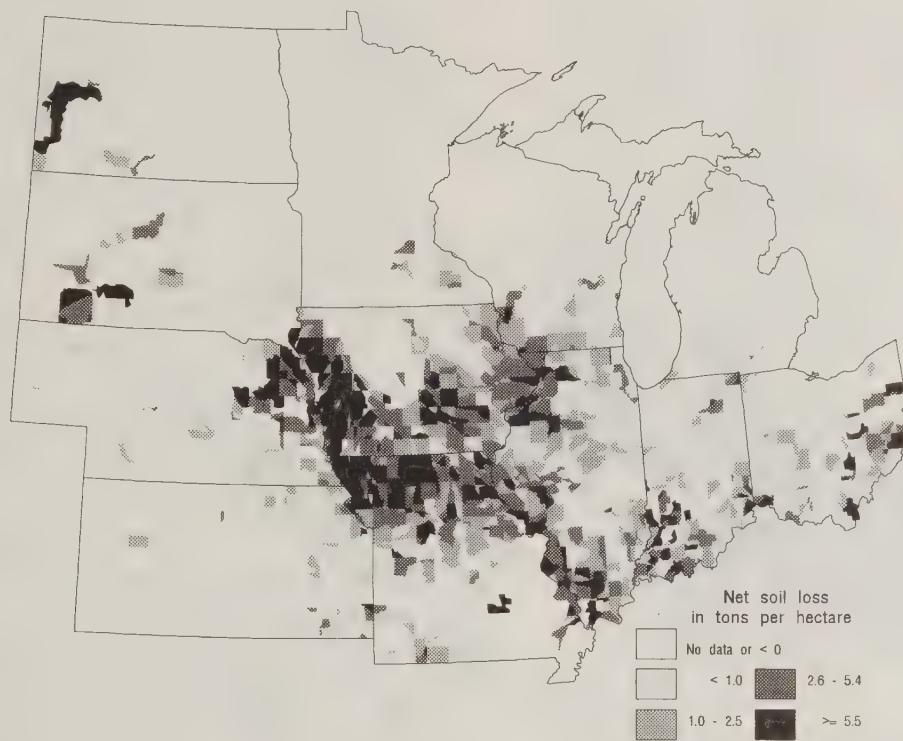
replace management and on-farm resources. These systems use the natural environment and can directly result in degradation of natural resources, notably land and water, that sustain agroecosystems (11). Conservation and protection of natural resources vital to agriculture is essential for sustaining long-term productivity.

Conservation practices selected from the NRI include conservation tillage, grassed waterways or outlets, strip or contour cropping, and terraces. Areas with one or more of these practices as a percentage of the total area are shown in Fig. 7. Soil conservation measures have demonstrated reduced erosion and discharge of sediment to surface waters in some areas. Many areas in the region with the greatest net soil losses (Fig. 6) are also areas with more than 38% of the land in conservation practices (Fig. 7). This raises questions about the effectiveness of conservation practices to control soil erosion. It is not clear if expanded implementation of conservation practices will be sufficient to reduce net soil loss to replacement levels in these areas.

Agricultural conservation program data compiled for the nation indicate little increase in land area with selected conservation and pollution abatement measures from 1982 to 1991 (17). The combination of all practices included in Fig. 7 were increased by only 5% in the last decade compared to the period 1936 to 1981 (17). Lack of erosion control exists even though some conservation practices, such as terraces, have been substantially expanded since 1981. Without a reversal in the soil loss seen in Fig. 6, particularly in the areas with more than 76% cropland and pasture (Fig. 2), the sustainability of

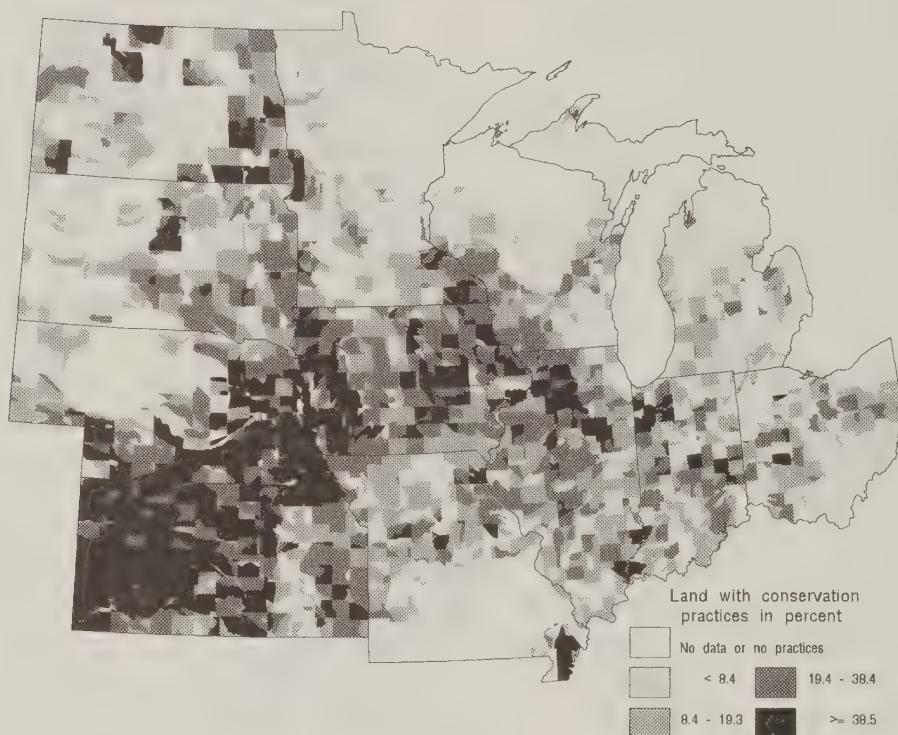
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**Figure 6. Net soil loss in tons per hectare**



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**Figure 7. Land with conservation practices in percent**



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existing agroecosystems in these areas is in question. The success of these systems was originally based on the uniquely productive natural resources of the region. However, the continued agricultural productivity now depends on increasing inputs of chemicals and energy. Unlike natural ecosystems, most cropland and pasture areas require inputs of auxiliary energy sources and nutrients to replace their loss through export of agricultural products and residues. Once the increase of inputs is restrained by economic or environmental considerations, a static input of chemicals and energy may prove inadequate to sustain agricultural production at existing levels, much less increase production.

### Conclusions

There is growing concern about the steady deterioration of natural resources including soil (8, 14), water (1, 15), and aquatic and terrestrial ecosystems (5, 19). These concerns are greatest in areas with intensive agricultural chemical and energy use, where water and land resources have been greatly modified by agriculture, and where natural ecosystems are particularly vulnerable to degradation from agricultural production. The questions now being asked specifically relate to exported chemical and sediment contaminants in water and air, and the potential impairment of land and water use.

The search for environmentally sustainable and economical agroecosystems requires regional scale investigations. At this scale the response of land and water resources to combinations of a broad range of agricultural activities and natural resource characteristics and conditions can be evaluated.

Agroecosystems research provides the theoretical framework for comprehending agricultural processes in the broadest manner and for characterizing the complex changes in natural resources to accommodate agriculture (10, 11). A regionally consistent data base organized in a geographic information system is a useful framework to examine agroecosystems characteristics. The spatial distribution of individual or combinations of variables in the NRI can be used to identify areas where modifications in cropping practices and landscape changes have the greatest potential to produce more economical and sustainable agroecosystems. Also, areas can be isolated where policies to improve off-site damage to valuable resources can be most effective. For example, knowing the location of major soil loss problems allows targeting of policy for corrective and mitigating action to conserve soil quality and quantity.

Recognition that humans are an integral part of the agroecosystem is needed to achieve a balance between conserving essential natural systems' components and sustaining human populations beyond the next production season or decade. To further understand agroecosystems, we need to characterize these systems through definition of the critical factors which control the interactions among elements of the systems. Conceptual and quantitative models can be used to integrate understanding of critical factors and the processes controlling natural resource components of agroecosystems such as soil, water, and biological resources.

The agroecosystem concept provides an ecological basis for research and development of more efficient and

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sustainable farming systems, as well as the opportunity to examine the cumulative effects of agricultural activities at regional, subregional, and watershed scales. While decisions and policies must still consider effects on individual farms, the long-term ecological changes affecting the sustainability of agriculture must also be viewed at larger scales. When the cumulative impact of agriculture on natural resources is measured over large areas, it becomes easier to recognize the more subtle impacts seen in smaller areas. For example, the loss of a few millimeters of soil from a field in a year may not appear to be substantial. However, when cumulative soil loss fills reservoirs with sediment, the off-site impacts imposed by current agricultural systems becomes clearer.

The application of a GIS to data such as the NRI, can be used to isolate areas where programs to mitigate resource degradation can be most effective. Geographic analysis can provide a basis to identify areas where research into causes of resource degradation will yield maximum information for solving natural resource concerns associated with agriculture. The release of the 1992 NRI timed for this conference will add a temporal dimension to the geographic analytical potential of each inventory. Completion of the digital geographic reference of NRI sample points will add further to the utility of the NRI in evaluating agricultural impacts on natural resources.

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#### Figure Captions

- Fig. 1. Frequency of occurrence of one or more natural vegetation assemblages including wetland systems, riparian areas, forests, and rangeland.
- Fig. 2. Frequency of land used for crops and pasture.
- Fig. 3. Frequency of cropland where at least four different crops were grown in 1979, 1980, 1981, and 1982.
- Fig. 4. Frequency of land with artificial drainage.
- Fig. 5. Frequency of land where irrigation supplies more than half of the crop water requirements.
- Fig. 6. Net soil loss.
- Fig. 7. Frequency of land with conservation practices to reduce soil erosion.

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# Rangeland Health: New Policies and Methods to Classify, Inventory, and Monitor Rangelands

By F. E. "Fee" Busby\*

The policy debate over the management of U. S. rangelands is not new but has escalated in the past few months.

"Rangeland Reform," is a hot topic in Congress, the Departments of Interior and Agriculture, and on ranches and in rural communities across the country. Serious disagreement over whether current management is improving, degrading, or sustaining rangeland ecosystems lies at the heart of this debate. Analysts, sometimes using the same data, have come to very different conclusions about the status of rangelands because the data available at the national level of aggregation to set priorities and policies for rangeland management were collected at different times, using different methods and criteria, and for purposes other than a national assessment of rangeland condition or health. Disagreements over the status of rangelands have been further complicated by an ongoing debate over the scientific validity of the rangeland assessment methods used by federal land management and technical assistance agencies.

The importance of protecting and sustaining the productive capacity of rangelands has been repeatedly recognized in national legislation (National Environmental Policy Act, National Forest Management Act, Federal Land Policy and Management Act, Soil and Water Resources Conservation Act, and the Public Rangeland Improvement Act). The Soil Conservation Service (SCS), Bureau of Land Management (BLM), and the Forest Service (FS) all have mandates to protect the quality and yield of renewable natural resources, but no standard methods have been established to evaluate whether these agencies are meeting their mandates. While the SCS conducts the National

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Resources Inventory (NRI) on non-federal lands, there is no equivalent assessment made of federal lands.

The National Research Council (NRC) committee on rangeland classification (Table 1) was formed in 1989 to examine the scientific basis of the methods used by federal agencies to classify, inventory, and monitor rangelands. In its report, released in January 1994, the committee recommended that the Departments of the Interior and Agriculture jointly: (1) define and adopt a minimum standard of what constitutes acceptable management and condition of U. S. rangelands, (2) develop consistent criteria and methods of data interpretation to evaluate whether rangeland management is meeting this standard, and (3) implement a coordinated and statistically valid national inventory to periodically evaluate the ecological health of federal and non-federal rangelands. These three steps, if implemented by federal agencies, would provide the consistent data and interpretations that are needed to ensure that the health of rangeland ecosystems is protected.

The committee carefully evaluated use of the word "health" realizing that rangelands are complex ecosystems, not individual organisms, and that analogies between the health of an organism and the health of an ecosystem could be misleading. The committee found, however, that health has been used to indicate the proper functioning of complex systems and is increasingly applied to ecosystems to indicate a condition in which ecological processes are functioning properly to maintain the structure, organization, and activity of the system over time. Webster's Third New International Dictionary defines healthy as

"(1) functioning properly or normally in its vital functions, (2) free from malfunctioning of any kind, and (3) productive of goods of any kind."

Healthy and unhealthy have been criticized as value laden terms that are inappropriately used in a scientific context. The assessment of rangelands, however, is more than a scientific endeavor.

Assessment could be designed to answer many different questions about rangelands, and the decision about which are the most important questions to answer is inextricably tied to the values that society attaches to rangelands.

Historically, the management of rangelands has focused on the production of livestock. Rangelands also produce water, minerals, energy, wood products, wildlife habitat, and are a repository of genetic materials. In recent decades, Americans have increasingly turned to rangelands for many purposes. They see rangelands as important areas for recreation and for the appreciation of natural beauty. They are concerned about the environmental condition of rangelands. Issues such as riparian zones, wilderness areas, biological diversity, threatened and endangered species, and wild horses and burros dominate much of the public's interest in rangelands. While measurement of certain attributes of rangeland ecosystems will be needed for specific management decisions (such as measuring forage production to estimate livestock carrying capacity), the committee concluded that there is a need for an assessment such as rangeland health that will characterize the overall status of the ecosystem.

It is essential that the results of rangeland assessments be communicated

**Table 1. Members and Staff, Committee on Rangeland Classification, National Research Council, Board on Agriculture.**

**Members:**

John C. Buckhouse, professor of rangeland watershed management, Department of Range-land Resources, Oregon State University, Corvallis

F. E. "Fee" Busby, (committee chair) director of U. S. programs, Winrock International Institute for Agricultural Development, Morrilton, Arkansas

Donald C. Clanton, rancher and professor of animal science (retired), University of Nebraska, North Platte

George C. Coggins, Frank Edwards Tyler Distinguished Professor of Law, University of Kansas Law School, Lawrence

Gary R. Evans, chief science advisor on global climate change, USDA, Washington, D. C.

Kirk L. Gadzia, president and owner of Resource Management Services, Bernalillo, New Mexico (during the study was director of education, Center for Holistic Resource Management, Albuquerque, New Mexico)

Charles M. Jarecki, cattle ranch owner and operator, Polson, Montana

Linda A. Joyce, rangeland research scientist, Rocky Mountain Forest and Range Experiment Station, U. S. Forest Service, USDA, Fort Collins, Colorado

Dick Loper, president and owner of Prairie Winds Consulting Service, Lander, Wyoming

Daniel L. Merkel, range conservationist, Soil Conservation Service, USDA, (assigned during the study to U. S. Environmental Protection Agency, Region 8), Denver, Colorado

George B. Ruyle, associate research scientist and range management extension specialist, School of Renewable Natural Resources, University of Arizona, Tucson

Jack W. Thomas, chief research wildlife biologist and project leader of the range and wildlife habitat research program, Pacific Northwest Forest and Range Experiment Station, U. S. Forest Service, USDA, La Grande, Oregon (became chief of U. S. Forest Service, Washington, D. C., December 1, 1993)

Johanna H. Wald, senior staff attorney, Natural Resources Defense Council, Washington, D. C.

Stephen E. Williams, professor of soils microbiology and head of the Department of Plant, Soil, and Insect Science, University of Wyoming, Laramie

**Staff:**

Craig A. Cox, senior staff officer, Board on Agriculture, National Research Council, Washington, D. C. (Became economist, Senate Committee on Agriculture, Nutrition, and Forestry, April 20, 1994)

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clearly and understandably to the public. Such communication is called for in the Resources Planning Act of 1974, the Soil and Water Resources Conservation Act (RCA) of 1977, and the Forest and Rangeland Renewable Resources Planning Act (RPA) of 1978, and is essential to the Environmental Monitoring and Assessment Program (EMAP) being implemented by the U. S. Environmental Protection Agency and the National Biological Survey (NBS) being conducted by the U. S. Fish and Wildlife Service. "Healthy" and "unhealthy" are terms the public intuitively understands. The committee decided that the advantages of using the terms to facilitate communication outweigh the problems with their use.

### Minimum Standard

The committee concluded that: "The lack of a consistently defined standard for acceptable conditions of rangeland ecosystems is the most significant limitation to current efforts to assess rangelands." Because fundamental questions about the condition of U. S. rangelands cannot be answered, our ability to make policy decisions about their worth, proper use and management, and investment for management, technical assistance, and research, is seriously impaired. The lack of agreed-to standards, coupled with divergent views on the proper interpretation of current assessment methods, confuses the public, the U. S. Congress, range scientists, and range users.

The committee recommended that "the minimum standard for rangeland management should be to prevent human-induced loss of rangeland health," and defined rangeland health as "the

degree to which the integrity of the soil and ecological processes of rangeland ecosystems are sustained." The following discussion explains what the committee meant by rangeland health, why it should serve as the minimum standard for acceptable conditions of rangelands, and the policy implications of the NRC report.

The capacity of rangelands to produce the commodities and satisfy the values desired by society depends on (1) the productivity of the soil, and (2) proper functioning of ecological processes such as soil development, nutrient cycling, energy capture and transfer, and plant community dynamics. The productive capacity of rangelands, in other words, depends on their health as defined by the committee. Loss of rangeland health is worrisome because soil degradation and disruption of ecological processes reduces, in some cases irreversibly, the productivity of rangeland ecosystems. Preventing human induced loss of rangeland health assures the public, policy makers, ranchers, and environmentalists that the productive capacity of rangelands is being sustained.

It is important to understand that the committee recommended rangeland health as a minimum ecological standard independent of the determination that the rangeland is suited to produce livestock, wildlife, or scenic beauty. If rangeland health is protected, a variety of management options and uses may be appropriate for any particular rangeland. The selected use(s) will depend on the preferences of the land owner if the rangeland is privately owned. On federal rangelands, decisions about use will be based on the relative values placed by society on different uses. Management and policy decisions about which uses,

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how much use, timing of use, and how use will be managed will often still be contentious, but they should at least be made in the context of protecting rangeland health.

### **Consistent Criteria and Data**

#### **Interpretation**

The committee concluded that the current confusion over the status of U. S. rangelands is exacerbated because different individuals, groups, and agencies use different definitions, methods, and terminology to evaluate the condition of rangelands. It is essential that government agencies, range users, and the public use the same criteria and interpret those criteria in the same way to evaluate rangeland health. The committee recommended that the health of rangeland be assessed by evaluating three sets of criteria: (1) the stability of soils and watersheds, (2) the integrity of nutrient cycles and energy flows, and (3) the functioning of ecological process that enable rangelands to recover from disturbance. Criteria and indicators suggested by the committee as a "first approximation" of rangeland health are listed in Table 2.

It is critical that all land management and technical assistance agencies charged with managing and inventorying rangeland resources interpret the data they collect in the same way. The committee recommended that all agencies classify rangeland as healthy if the data indicate that the stability of soils, watersheds, and ecological processes and the productive capacity is being sustained; at risk if current conditions indicate a reversible loss in productivity but an increased vulnerability to further degradation; and

unhealthy if degradation has resulted in change in soil and watershed stability, ecosystem function, and a loss of productivity that cannot be reversed without external inputs such as reseeding or soil reclamation.

An assessment of rangeland health, whether done as part of the management program for a ranch, allotment, or forest, or as the basis for a national assessment should be only one part of larger effort to gather and analyze information about rangelands. Rangeland health assessments are intended to determine whether the capacity to produce commodities and satisfy values is being protected, and, if not, alert the manager to the need for additional analysis of the situation and the possible need for change in the current management program.

A rangeland health evaluation will not determine conclusively the cause of current conditions or determine what changes in management are required, or how a particular area of rangeland should be used. The determination of which uses and management practices are appropriate will require the evaluation of additional data such as plant species composition, productivity, and utilization. No single index will meet all the needs of rangeland assessment and management.

### **Statistically Valid National Inventory and Monitoring System**

The committee concluded that current inventories are inadequate as statistically valid estimates of the proportion of the nation's rangelands that are healthy, at risk, or unhealthy, because they were conducted (1) as part of allotment, pasture, or ranch management inventories and were never intended to be aggregated in a

**TABLE 2. Rangeland Health Evaluation Matrix**

| <i>Indicator</i>   | <i>Healthy</i>   | <i>At Risk</i>   | <i>Unhealthy</i>   |
|--|--|--|--|
| <i>Phase 1: Soil stability and watershed function</i>            |  |  |  |
| A horizon  | Present and distribution unfragmented  | Present but fragmented distribution developing   | Absent, or present only in association [with] prominent plants or with other obstructions            |
|  |  |  |  |
| Pedestaling  | No pedestaling of plants or rocks  | Pedestals present, but on mature plants only; no roots exposed   | Most plants and rocks pedestaled; roots exposed  |
| Rills and gullies  | Absent, or with blunted and muted features                                     | Small, embryonic, and not connected into a dendritic pattern   | Well defined, actively expanding, dendritic pattern established                                      |
| Scouring or sheet erosion  | No visible scouring or sheet erosion   | Patches of bare soil or scours developing  | Bare areas and scours well developed and contiguous  |
| Sedimentation or dunes   | No visible soil deposition   | Soil accumulating around plants or small deposits or dunes   | Soil accumulating in large barren obstructions or behind large obstructions                          |
| <i>Phase 2: Distribution of nutrient cycling and energy flow</i> |  |  |  |
| Distribution of plants   | Plants well distributed across site  | Plant distribution becoming fragmented   | Plants clumped, often in association with prominent individuals; large bare areas between clumps     |
| Litter distribution and incorporation                            | Uniform across site  | Becoming associated with prominent plants or other obstructions  | Litter largely absent  |
| Root distribution  | Community structure results in rooting throughout the available soil profile   | Community structure results in absence of roots from portions of the available soil profile            | Community structure results in rooting in only one portion of the available soil profile             |
| Distribution of photosynthesis                                   | Photosynthetic activity occurs throughout the period suitable for plant growth | Most photosynthetic activity occurs during one portion of the period suitable for plant growth         | Little or no photosynthetic activity on location during most of the period suitable for plant growth |
| <i>Phase 3: Recovery mechanisms</i>                              |  |  |  |
| Age class distribution   | Distribution reflects all species  | Seedlings and young plants missing   | Primarily old or deteriorating plants present  |
| Plant vigor  | Plants display normal growth form  | Plants developing abnormal growth form   | Most plants in abnormal growth form  |
| Germination microsite  | Microsites present and distributed across the site                             | Developing crusts, soil movement, or other factors degrading microsites; developing crusts are fragile | Soil movement or crusting sufficient to inhibit most germination and seedling establishment          |

SOURCE: National Research Council. 1994. Rangeland Health: New Methods to Classify, Inventory and Monitor Rangelands.

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statistically valid way to a national level, and (2) at different times using different methods and were interpreted using inconsistent concepts and definitions. The National Resources Inventory (NRI) conducted periodically on nonfederal rangelands by the SCS is based on a statistically valid sampling scheme but currently does not collect or interpret the data needed to assess rangeland health as defined by the committee.

The committee strongly recommended that the Secretaries of Agriculture and of the Interior, and the Administrator of the Environmental Protection Agency (1) convene an interagency task force to develop, test, and standardize methods to assess rangeland health, and (2) develop coordinated plans for implementing a periodic sampling system on federal and nonfederal rangelands that will produce statistically valid estimates of the proportion of rangelands that are healthy, at-risk, or unhealthy. Since the NRC report was released the interagency task force has been formed and is actively working to accomplish these recommendations.

Establishing a coordinated, statistically valid national assessment system, will require new tools, more money, and time. The committee concluded, however, that the pay-off from such an investment would be large. Statistically valid and periodic estimates of the proportion of rangelands that are healthy, at risk, or unhealthy would provide national policy makers and the public with the information they need to determine whether national policies are protecting the productive capacity of U. S. rangelands. Debates over national policy could still be contentious, but would at least be based on a credible, common data

set available for independent review by academics, officials, ranchers and, environmentalists.

### **Transition to Rangeland Health Assessment**

The committee strongly recommended that current methods of assessing rangeland condition not be abandoned until new systems are in place. As progress is made toward more comprehensive and standardized assessments of rangelands, there are important intermediate steps that can be taken now to substantially increase the information available and the understanding needed to determine whether rangelands are healthy, at risk, or unhealthy. Indicators of soil surface condition should be immediately added to all current and ongoing assessments of rangelands that are made as part of management programs for a pasture, ranch, or allotment, or as part of regional or national assessments of rangelands. Data on plant composition and production already collected for management or inventory purposes using current methods should be evaluated for possible use to assess nutrient cycling, energy flows, and recovery mechanisms. These will be important steps toward a more comprehensive evaluation of rangeland health.

Progress can be made toward preventing human-induced loss of rangeland health with the tools and understanding we already have at our disposal. Comprehensive assessments of rangeland health, however, will require more knowledge. The committee called on the Secretaries of Agriculture and of the Interior, and the Administrator of the Environmental Protection Agency to

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initiate a coordinated research effort in several basic and applied areas. An unimproved understanding of the relationship between soil properties and rangeland health is essential. The lack of experience with and testing of indicators of nutrient cycling and energy flows are impediment to the development of a comprehensive system to determine whether rangelands are healthy, at-risk, or unhealthy. Ecosystem factors that contribute to or prevent recovery of rangeland health need to be better understood.

A rangeland health evaluation will not determine conclusively the cause of current conditions or determine what changes in management are required, or how a particular area of rangeland should be used. The determination of which uses and management practices are appropriate will require the evaluation of additional data such as plant species composition, productivity, and utilization. No single index will meet all the needs of rangeland assessment and management.

### **Summary**

There is no doubt that the capacity of some rangelands to produce commodities and satisfy values is threatened. Overgrazing, harmful recreational activities, wildfire, disease and insect outbreaks, drought, and other factors have seriously degraded some rangelands in the past, and unfortunately, degradation occurs on some lands today. Degradation reduces the diversity and amount of the commodities and values that rangelands provide, and limits the options for use by future generations. Severe degradation can be irreversible on a practical time scale and with available resources. The need to

identify which rangelands are threatened and determine the severity of those threats is urgent.

The NRC committee on rangeland classification has suggested a first approximation of how rangeland health can be evaluated. It will be difficult to develop methods of rangeland health that are suitable for use by rangeland managers who provide technical assistance to ranchers or who must administer large areas of federal rangeland, and by scientists who conduct national-level inventories of rangelands. New partnerships between range users, managers, range scientists, and other ecologists working in different ecosystems and different institutions are needed. The barriers to coordination between federal agencies working with different mandates and traditions will have to be overcome.

Answering the question, "Are our rangelands healthy?" may be the most important contribution range scientists and managers can make to resolving the policy debate over use and management of federal and nonfederal rangelands. Answering this question will provide information that is urgently needed by ranchers, environmentalists, range managers, scientists, and policy makers. Answering this question will be an important step toward sustaining the ecological integrity and productivity of these important ecosystems.

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# Emerging Opportunities for the NRI

By Clayton W. Ogg\*

Several speakers have suggested that national survey data can play a powerful role in helping policy makers anticipate the consequences of new policy initiatives.

Perhaps the best example of the power of new information is the NRI, itself, which provided policy makers an opportunity in the early eighties to craft new conservation programs suited to policy makers's emerging soil conservation concerns.

Knowing with some certainty what new conservation initiatives would accomplish and what lands would be affected played a key role in the 1985 farm bill's conservation initiatives, which led to major commitments of resources (9).

The National Academy of Science's (NAS) recent work, Soil and Water Quality, An Agenda for Agriculture (8), which Craig Cox described, articulates a policy agenda that is emerging today, which includes a greater focus on protecting ecological systems and water quality. Use of riparian borders along permanent streams and grassed waterways along concentrated flow areas makes up one of the study's four major remedies offered to achieve this ecological/water quality focus. The NRI could provide information regarding riparian systems which would help shape environmental policy development today, just as the 1977 NRI's soil erosion information shaped soil conservation policy twenty years ago.

## Information Needs Regarding Status of Riparian Systems and Grassed Waterways

Studies at a number of sites suggest that presence of riparian borders and grassed waterways can reduce stream loadings of sediment by 50 percent (8), phosphorus by 30 percent (6), and nitrates

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and some herbicides by as much as 90 percent (1,2,3,4,5,7,10), while providing shade and corridors that benefit aquatic and terrestrial creatures. However, actual water quality performance of riparian systems varies widely depending, for example, on wetness of the soil along the stream corridor (2,8). While these findings stimulate much interest in supporting establishment of riparian borders, data is limited about the current status of stream corridors, or about the amount of land that might be affected by a national initiative aimed at converting cropland along streams to riparian uses.

Analysis is underway to identify how many fields in the U.S. drain into streams in "lowland" areas which, according to the NAS analysis (8), have the highest probability of substantially reduced nitrate loadings if we convert stream borders to riparian uses. In these lowland areas, hydric soils are more likely to occur adjacent to the stream than in upland areas. The resulting wetness facilitates denitrification of nitrates passing under the proposed riparian systems through subsurface flows.

Future NRI's could provide, with slight modification, much information about the status of the nation's stream corridors and grassed waterways. Currently, the NRI only indicates nearness of streams or water bodies to the field's sampled point. This information could be expanded to indicate status or existence of grassed waterways or riparian borders on the field. Knowing how many fields need additional land placed in riparian uses or grassed waterways would facilitate much more accurate estimation of the costs of a national initiative to establish those systems.

## Other Opportunities

Supplying these and other data needs regarding the nation's riparian systems represents a major opportunity, once again, for the NRI to play a key role in the development of sound resource policies. Other opportunities have been raised by speakers at this conference. The challenge is to provide information that focuses on policy maker's current concern for attaining ecological and environmental objectives.

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The NRI database is available to the public on four CD-ROMs (ISO 9660 format) at \$50 per disk. Each disk contains data for a collection of states that form a contiguous region, organized as follows:

- CD #1, West—Arizona, California, Colorado, Hawaii, Idaho, Montana, Nevada, New Mexico, Oregon, Utah, Washington, Wyoming.
- CD #2, South—Alabama, Arkansas, Caribbean Area, Florida, Georgia, Kentucky, Louisiana, Mississippi, North Carolina, Oklahoma, South Carolina, Tennessee, Texas.
- CD #3, Midwest—Illinois, Indiana, Iowa, Kansas, Michigan, Minnesota, Missouri, Nebraska, North Dakota, Ohio, South Dakota, Wisconsin.
- CD #4, Northeast—Connecticut, Delaware, Maine, Maryland, Massachusetts, New Hampshire, New Jersey, New York, Pennsylvania, Rhode Island, Vermont, Virginia, West Virginia.

Results for Alaska are not included in the present release; they will be provided later.

Each disk includes separate files containing the Soil Interpretations Records and spatial datasets for mapping NRI data (see "Spatial Datasets," below).

All files are flat ASCII files. The full database for the entire country, including the soils data, is about 1.3 gigabytes. Data can be downloaded on a state-by-state basis if disk storage space is

limited. Database documentation will be provided.

### Spatial Datasets

Spatial datasets of boundaries of Major Land Resource Areas, 8-digit hydrologic units, and counties are provided on the CDs (with and without Federal lands). These spatial datasets contain the same spatial identifiers used in the NRI database, allowing NRI users to create interpretive maps; the data are provided in U.S. Geological Survey DLG-3 formatted files. GRASS-GIS vector formatted files are included with the Data Analysis Software. Documentation on spatial databases is provided.

### Data Analysis Software

The Natural Resources Conservation Service has developed NRI Data Analysis Software that helps users query and generate reports and maps. It is easy to use, graphical, and Windows-oriented. Users make selections from menus to create reports and maps. Prior knowledge of the database management system, the computer operating system, or the geographic information system is not needed to create reports or maps. The Data Analysis Software has a utility for importing all or portions of the NRI into the database management system. Reports resulting from the NRI query can be output to a printer, plotter, or computer file. The Data Analysis Software is provided with NRI and spatial data that have been specially formatted to run with the software. The two-tape set is available on 8mm tape only, at a cost of \$100 per set. Software documentation is provided.

Hardware and software requirements for running the Data Analy-

sis Software (v. 1.0) include:

- SPARC compliant graphics workstation with 32 megabytes RAM;
- Solaris 1.x operating system;
- 8mm tape drive;
- 2.5 gigabytes of storage space, which includes sufficient space to load the complete database;
- INFORMIX database management system (v. 5.01 or later);
- GRASS/MAPGEN (v. 4.12);
- XIIR4 X Windows graphical user interface (Motif window manager is recommended).

### Where to Go for Help

To obtain the NRI database, Data Analysis Software, and spatial data sets, contact:

Natural Resources Conservation Service  
National Cartography and GIS Center  
Fort Worth Federal Center  
Bldg 23, Room 60  
P.O. Box 6567  
Fort Worth, Texas 76115-0567  
1-800-672-5559

For additional information on the NRI program, contact:

Natural Resources Conservation Service  
Natural Resources Inventory Division  
P.O. Box 2890  
Washington, DC 20013  
202-720-5420

Information on the NRI and its use is available on the Internet. Type: "<http://www.nhq.ncrs.usda.gov/nri.html>".

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